APPENDIX G
SETTLEMENT ANALYSES

APPENDIX G.1	FOUNDATION SETTLEMENT
APPENDIX G.2	CLAY LINER RATE OF CONSOLIDATION
APPENDIX G.3	CLAY LINER CONSOLIDATION SETTLEMENT
APPENDIX G.4	POST-CLOSURE WASTE SETTLEMENT

APPENDIX G.1
FOUNDATION SETTLEMENT

Objectives:

1. To estimate the magnitude and distribution of settlement of the Landfill B-18 foundation due to the overlying waste.

2. To evaluate whether the final gradient of the Landfill B-18 foundation after settlement is the required minimum of 2% to maintain adequate drainage.

Given:

The Landfill B-18 expansion geometry and as-built landfill configuration used to generate the evaluated sections were obtained from AutoCAD drawings (see Drawings). All other data used for these calculations are based on the original Environmental Solutions, Inc. (ESI, 1990) calculations, including site geology and foundation stratigraphy (see Attachment 1). The original calculation was performed utilizing the computer program SETTLG developed by Geosoft Inc.; however, this program is no longer available. Golder programmed the settlement equations into Microsoft Excel to perform the foundation settlement calculations.

Assumptions (Assumptions are consistent with those used by ESI):

1. Claystone and siltstone are considered the same. Previous investigations indicate that the compression characteristics of the claystone and siltstone are practically the same.

2. Foundation materials are highly overconsolidated, therefore the stress-strain relationship under loading is considered to be within the elastic range of materials.

3. Rebound and settlement of foundation will occur during excavation and waste placement. Therefore the gross weight, rather than the net weight of the waste fill will be used.

4. Sandstone under the landfill foundation is considered to be incompressible.

5. The foundation materials are considered to be homogeneous and isotropic. The stress-strain behavior of the materials under load is characterized by the Young's Modulus and the Poisson's Ratio.

Method:

1. Determination of Young's Modulus (E)

   The elastic modulus may be expressed in terms of the shear strength of the soil:

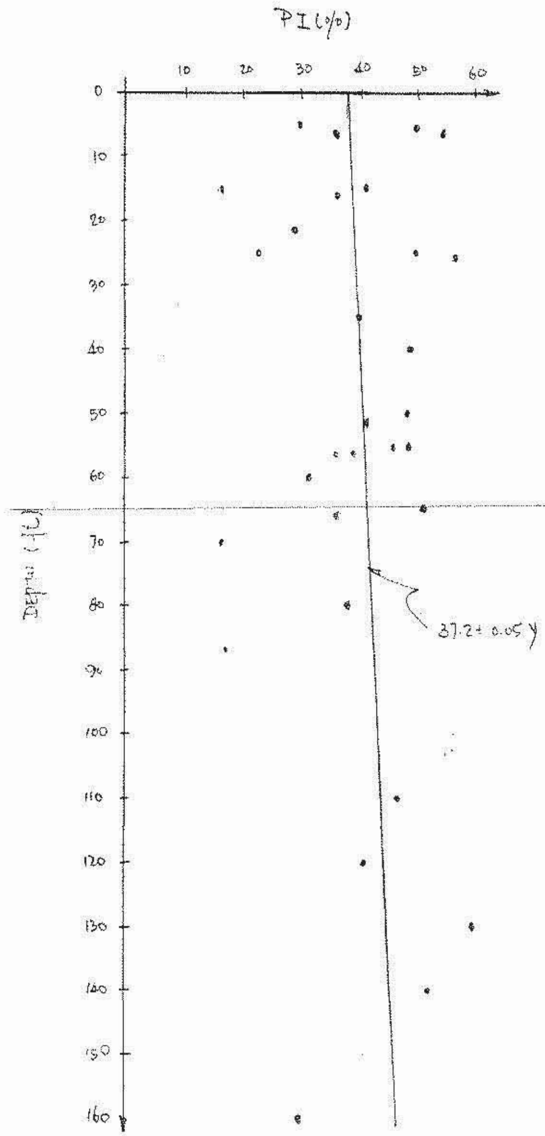
$$E = kS_u$$

   Where k is a function of the Plasticity Index (PI). Values for the on-site claystone materials at various depths are shown in Figure 1. By using the linear progression method, the scattered data may be represented by a straight line. The best fit straight line takes the form of:

$$\text{PI } (\%) = 37.2 + 0.05y \text{ (ft)}$$

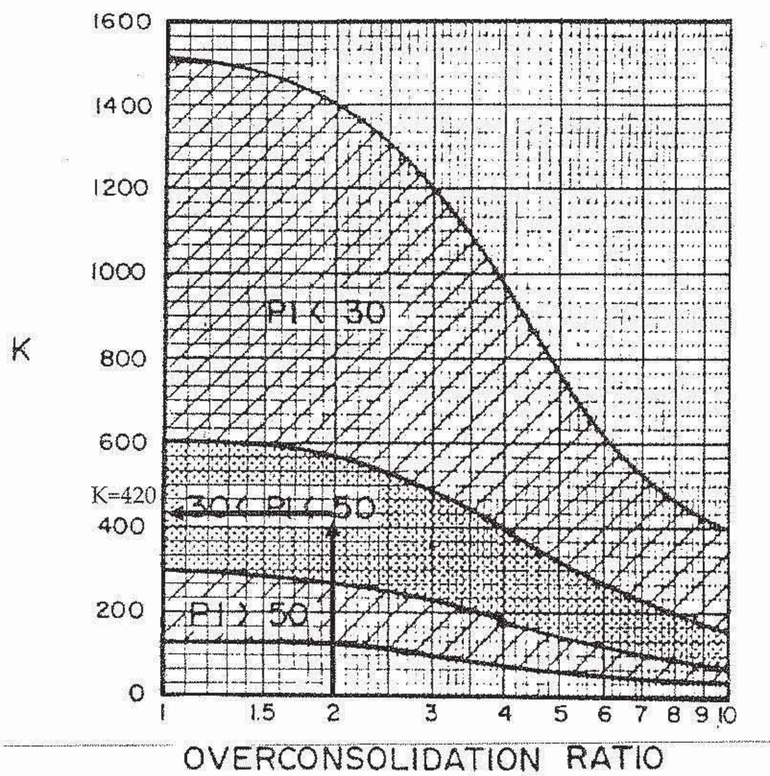
where y is equal to the depth below ground surface. The results of the above statistical analysis indicate that the variation of PI with depth is not significant.

Figure 1: PI vs. Depth for claystone material.



Therefore, it was assumed that the PI is constant with depth. Taking the average depth for all data, the PI value for the foundation material was estimated to be approximately 41. By assuming the overconsolidation ratio (OCR) of the claystone is 2, the value of K was estimated to be 420 as shown in the Figure 2.

Figure 2: Chart for estimating Undrained Modulus of Clay.



$E_u = KS_u$

E_u = UNDRAINED MODULUS OF CLAY

K = FACTOR FROM CHART ABOVE

S_u = UNDRAINED SHEAR STRENGTH OF CLAY

The shear strength of the foundation material is summarized in the following table:

Geologic Unit	Shear Strength (psi)[1]
18-5	127.0
18-7	110.6
18-8	91.1
18-12	72.2
Average	100.2

[1]Obtained from UU triaxial test results

Taking the average shear strength (S_u), the elastic modulus (E_u) is estimated to be:
Eu = K x Su = 420 x (100 lb/in^2 x 144 in^2/ft^2 / 1000 lb/kip) = 6,048 kip/ft^2, round to 6,000 ksf.

2. Determination of Poisson's Ratio (ν)
The value of Poisson's Ratio was found to be insensitive to the compressibility coefficient used to calculate the settlement. Poisson's Ratio was back-calculated using the average compressibility coefficient determined by using a value of the Poisson's Ratio from 0 to 0.5. The resulting Poisson's Ratio was estimated to be 0.38.

3. Determination of Compressibility Index (C_u)
The Compressibility coefficient is related to E and ν by:

$$C_u = \frac{1-\nu^2}{E}$$

4. Determination of changes in stress with depth ($\Delta\sigma$)
Since it was assumed that the deformation of the foundation is elastic under the waste loading, the Boussinesq Equation was used to determine $\Delta\sigma$. To calculate $\Delta\sigma$ under the center of a rectangular loaded area:

$$\Delta\sigma = \sigma_0 m I$$

Where:

σ_0 = initial stress at a specific depth
m = number of influences, for the center of a foundation m = 4
$\sigma_0 = \gamma z$
γ = soil unit weight
z = depth to the middle of layer to be evaluated

$$I = \frac{1}{4\pi}\left[\frac{2MN\sqrt{V}}{V+V_1}\frac{V+1}{V} + \tan^{-1}\left(\frac{2MN\sqrt{V}}{V-V_1}\right)\right]$$

$$M = \frac{B}{z};\ N = \frac{L}{z}$$

$V = M^2 + N + 1;\ V_1 = (MN)^2$
B = Base of foundation
L = Length of foundation

To calculate $\Delta\sigma$ under a point that is not at the center of the rectangular loaded area, the following is used:

$$\Delta\sigma = \sigma_0 I_1 + \sigma_0 I_2 + \sigma_0 I_3 + \sigma_0 I_4$$

5. Calculation of Settlement (ΔH)
The foundation settlement can then be calculated by:

$$\Delta H = \varepsilon H$$

Where:

ε = vertical strain determined by $\varepsilon = \Delta\sigma C_u$
H = thickness of the layer where settlement is calculated

The total settlement is determined by $\sum \Delta H$ under the point being evaluated.

Calculations and Results:

1. Settlement Calculation
Foundation settlement calculations were performed for Sections 1-1', 2-2', and 3-3' for each of the points shown on Drawing 1, Cross sections are shown on Drawings 3, 4 and 5, respectively. All settlement results are summarized in the Table 1 through Table 3 in the Tables Section of this calculation brief. Settlement along the landfill foundation ranges from 0.74 inches (Section 2-2' Point 2A) to 13.55 inches (Section 2-2 Point $2K_1$)).

2. Final Gradient Computation
The formula utilized for the final gradient calculation is defined as follows:

$$G_f = \frac{(EL_2 - \Delta H_2) - (EL_1 - \Delta H_1)}{(\Delta X_2 - \Delta X_1)}$$

Where:

EL_2 = elevation at point 2
EL_1 = elevation at point 1
ΔH_2 = settlement at point 2
ΔH_1 = settlement at point 1
(ΔX_2-ΔX_1) = Distance between two points

Final gradient calculations were performed in Sections 2-2' and 3-3'(as shown on Drawing 4 and 5) since the two sections are the ones along the drainage direction. All final gradient results are summarized in Table 4 and Table 5 in the Tables Section of this report.

In all cases the gradient remains in excess of 2% when measured in the direction of flow. Some locations in the sections are not perpendicular to the contours and therefore the slope is not reported; however, the computed settlement at these locations are observed to be of similar magnitude and the original grade would be maintained.

3. Strain Difference Computation

The formula utilized for the final gradient calculation is defined as follows:

$$\Delta\varepsilon = \frac{G_f - G_i}{d}$$

In where:

G_f = final gradient
G_i = initial gradient
d = distance between two points

Final strain calculations were performed in Sections 2-2' and 3-3'since these two sections are the ones along the drainage direction. All strain difference results are summarized in Table 6 through Table 7 in the Tables Section of this report.

The result all points have less than the design maximum strain of 0.1%.

Conclusions:

Based on the foundation settlement calculations for the selected sections, we can assume that the bottom gradient of the landfill along the critical sections will be maintained at a minimum of 2% meeting the minimum requirement for drainage.

Based on the foundation settlement calculations for the selected sections, we can assume that there will be no abrupt changes along the surface of the foundation due to settlement. The maximum allowable strain due to settlement is less than 0.1% which is less than the yield strain of the synthetic liner. Therefore the liner stays intact.

Reference:

Environmental Solutions, Inc. (ESI), "Engineering and Design Report, Landfill Unit B-18, Phases I and II and Final Closure, Kettleman Hills Facility," August 1990, Appendix G.1.

Bowles, J.E., "Foundation Analysis and Design," Fifth Edition, 1996, pp. 291-296.

Table 1
Settlement Calculation Summary
Section 1-1'

Point No.	A Geoligic Unit	B % Clay in A	C Calculated Settlement (assumed a 100% Clay Content) (in)	BxC Estimated Settlement (in)	Total Settlement (in)
1 A	18-7	30%	11.90	3.57	3.57
1 B	18-7	30%	13.85	4.16	4.16
1 C	18-8	100%	3.14	3.14	7.74
	18-7	30%	15.35	4.60	
1 D	18-8	100%	5.71	5.71	8.52
	18-7	30%	9.38	2.82	
1 E	18-9	0%	0.00	0.00	8.99
	18-8	100%	6.24	6.24	
	18-7	30%	9.17	2.75	
1 F	18-9	0%	0.00	0.00	11.18
	18-8	100%	8.26	8.26	
	18-7	30%	9.75	2.93	
1 G	18-9	0%	0.00	0.00	12.63
	18-8	100%	9.50	9.50	
	18-7	30%	10.43	3.13	
1 H	18-10	50%	4.72	2.36	9.63
	18-9	0%	0.00	0.00	
	18-8	100%	6.24	6.24	
	18-7	30%	3.41	1.02	
1 I	18-10	50%	6.55	3.28	5.47
	18-9	0%	0.00	0.00	
	18-8	100%	2.10	2.10	
	18-7	30%	0.33	0.10	
1 J	18-12	100%	0.69	0.69	1.80
	18-11	10%	1.48	0.15	
	18-10	50%	1.27	0.63	
	18-9	0%	0.00	0.00	
	18-8	100%	0.32	0.32	
1 K	18-13	10%	1.46	0.15	1.20
	18-12	100%	0.01	0.01	
	18-11	10%	0.99	0.10	
	18-10	50%	1.25	0.63	
	18-9	0%	0.00	0.00	
	18-8	100%	0.32	0.32	

Table 2
Settlement Calculation Summary
Section 2-2'

Point No.	A Geoligic Unit	B % Clay in A	C Calculated Settlement (assumed a 100% Clay Content) (in)	BxC Estimated Settlement (in)	Total Settlement (in)
2 A	18-4	100%	0.28	0.28	0.74
	18-3	20%	2.32	0.46	
2 B	18-5	20%	0.61	0.12	2.43
	18-4	100%	0.62	0.62	
	18-3	20%	8.43	1.69	
2 C	18-5	20%	2.56	0.51	2.90
	18-4	100%	0.81	0.81	
	18-3	20%	7.91	1.58	
2 D	18-6	20%	1.33	0.27	3.62
	18-5	20%	2.78	0.56	
	18-4	100%	0.96	0.96	
	18-3	20%	9.18	1.84	
2 E	18-7	30%	3.15	0.95	4.62
	18-6	20%	1.63	0.33	
	18-5	20%	3.14	0.63	
	18-4	100%	1.21	1.21	
	18-3	20%	7.57	1.51	
2 F	18-7	30%	7.57	2.27	5.92
	18-6	20%	1.90	0.38	
	18-5	20%	3.38	0.68	
	18-4	100%	1.49	1.49	
	18-3	20%	5.54	1.11	
2 G	18-8	100%	8.96	8.96	11.94
	18-7	30%	8.55	2.57	
	18-6	20%	2.07	0.41	
	18-5	20%	3.10	0.62	
	18-4	100%	1.22	1.22	
2 H	18-8	100%	1.22	1.22	5.14
	18-7	30%	9.21	2.76	
	18-6	20%	2.32	0.46	
	18-5	20%	3.47	0.69	
2 I	18-10	50%	0.63	0.31	6.45
	18-9	0%	0.00	0.00	
	18-8	100%	5.17	5.17	
	18-7	30%	2.74	0.82	
	18-6	20%	0.71	0.14	
2 J	18-10	50%	4.46	2.23	13.32
	18-9	0%	0.00	0.00	
	18-8	100%	9.10	9.10	
	18-7	30%	6.63	1.99	

Table 2
Settlement Calculation Summary
Section 2-2'

Point No.	A Geoligic Unit	B % Clay in A	C Calculated Settlement (assumed a 100% Clay Content) (in)	BxC Estimated Settlement (in)	Total Settlement (in)
2 K	18-10	50%	6.71	3.36	11.58
	18-9	0%	0.00	0.00	
	18-8	100%	7.54	7.54	
	18-7	30%	2.28	0.68	
2 K_1	18-10	50%	8.39	4.20	13.55
	18-9	0%	0.00	0.00	
	18-8	100%	7.81	7.81	
	18-7	30%	5.13	1.54	
2 L	18-10	50%	9.20	4.60	9.89
	18-9	0%	0.00	0.00	
	18-8	100%	5.09	5.09	
	18-7	30%	0.65	0.19	
2 M	18-11	10%	2.45	0.25	5.83
	18-10	50%	6.24	3.12	
	18-9	0%	0.00	0.00	
	18-8	100%	2.47	2.47	
2 N	18-12	100%	1.36	1.36	5.29
	18-11	10%	1.92	0.19	
	18-10	50%	3.23	1.62	
	18-9	0%	0.00	0.00	
	18-8	100%	2.12	2.12	
2 O	18-13	10%	2.91	0.29	1.25
	18-12	100%	0.42	0.42	
	18-11	10%	0.55	0.06	
	18-10	50%	0.97	0.48	
	18-9	0%	0.00	0.00	

Table 3
Settlement Calculation
Section 3-3'

Point No.	A Geoligic Unit	B % Clay in A	C Calculated Settlement (assumed a 100% Clay Content) (in)	BxC Estimated Settlement (in)	Total Settlement (in)
3 A	18-13	10%	14.10	1.41	1.41
3 B	18-13	10%	22.54	2.25	2.25
3 C	18-12	100%	4.07	4.07	5.79
	18-13	10%	17.24	1.72	
3 D	18-11	10%	10.13	1.01	4.89
	18-12	100%	3.73	3.73	
	18-13	10%	1.53	0.15	
3 D_1	18-10	50%	8.40	4.20	8.37
	18-11	10%	6.98	0.70	
	18-12	100%	3.18	3.18	
	18-13	10%	2.97	0.30	
3 D_2	18-10	50%	10.00	5.00	8.46
	18-11	10%	7.72	0.77	
	18-12	100%	2.55	2.55	
	18-13	10%	1.39	0.14	
3 D_3	18-10	50%	11.36	5.68	9.09
	18-11	10%	7.95	0.79	
	18-12	100%	2.61	2.61	
	18-13	10%	0.78	0.08	
3 E	18-10	50%	13.23	6.61	9.65
	18-11	10%	7.39	0.74	
	18-12	100%	2.29	2.29	
3 F	18-10	50%	11.58	5.79	5.79

Table 4
Grade Calculation
Section 2-2'

Point No.	Initial Elevation (ft)	Settlement (ft)	Final Elevation (ft)	Distance (ft)	Initial Grade (%)	Final Grade (%)	Allowable Grade 2.0%
2 A	739.09	0.06	739.03				
				108.83	29.41%	29.54%	OK
2 B	707.08	0.20	706.88				
				112.14	2.18%	2.15%	OK
2 C	709.53	0.24	709.29				
				Not connected with same slope			
2 D	710.65	0.30	710.35				
				139.54	2.34%	2.28%	OK
2 E	713.91	0.39	713.52				
				Not perpendicular to the slope			
2 F	716.55	0.49	716.06				
				297.93	2.42%	2.25%	OK
2 G	723.75	0.99	722.76				
				41.39	2.42%	3.78%	OK
2 H	724.75	0.43	724.32				
				95.62	44.72%	44.61%	OK
2 I	767.51	0.54	766.97				
				Not connected with same slope			
2 J	742.76	1.11	741.65				
				85.61	8.29%	8.12%	OK
2 K	735.66	0.96	734.70				
				58.91	2.29%	2.01%	OK
2 K_1	737.01	1.13	735.88				
				35.67	44.46%	45.32%	OK
2 L	752.87	0.82	752.05				
				60.9	44.55%	45.10%	OK
2 M	780.00	0.49	779.51				
				33.99	49.60%	49.73%	OK
2 N	796.86	0.44	796.42				
				Not connected with same slope			
2 O	837.27	0.10	837.17				

Table 5
Grade Calculation
Section 3-3'

Point No.	Initial Elevation (ft)	Settlement (ft)	Final Elevation (ft)	Distance (ft)	Initial Grade (%)	Final Grade (%)	Allowable Grade 2.0%
3 A	745.79	0.12	745.67				
				144.24	2.49%	2.54%	OK
3 B	742.2	0.19	742.01				
				130.45	2.42%	2.65%	OK
3 C	739.04	0.48	738.56				
				320.67	2.33%	2.31%	OK
3 D	731.57	0.41	731.16				
				266.92	2.32%	2.43%	OK
3 D_1	725.37	0.70	724.67				
				Not connected with same slope			
3 D_2	734.00	0.70	733.30				
				Not connected with same slope			
3 D_3	725.27	0.76	724.51				
				63.73	2.10%	2.10%	OK
3 E	726.61	0.76	725.85				
				396.01	2.46%	2.45%	OK
3 F	736.35	0.80	735.55				
				Not connected with same slope			
8	837.27	0.48	836.79				

Table 6
Strain Calculation
Section 2-2'

Point No.	Initial Elevation (ft)	Distance (ft)	Initial Grade (%)	Final Grade (%)	$\Delta\varepsilon$	Allowable Strain 0.1%
2 A	739.09					
		108.83	29.41%	29.54%	0.0012%	OK
2 B	707.08					
		112.14	2.18%	2.15%	0.0003%	OK
2 C	709.53					
		70.61	1.59%	1.50%	0.0012%	OK
2 D	710.65					
		139.54	2.34%	2.28%	0.0004%	OK
2 E	713.91					
		147.10	1.79%	1.72%	0.0005%	OK
2 F	716.55					
		297.93	2.42%	2.25%	0.0006%	OK
2 G	723.75					
		41.39	2.42%	3.78%	0.0331%	OK
2 H	724.75					
		95.62	44.72%	44.61%	0.0012%	OK
2 I	767.51					
		Not connected with same slope				
2 J	742.76					
		85.61	8.29%	8.12%	0.0020%	OK
2 K	735.66					
		58.91	2.29%	2.01%	0.0047%	OK
2 K_1	737.01					
		35.67	44.46%	45.32%	0.0240%	OK
2 L	752.87					
		60.90	44.55%	45.10%	0.0091%	OK
2 M	780.00					
		33.99	49.60%	49.73%	0.0039%	OK
2 N	796.86					
		Not connected with same slope				
2 O	837.27					
		162.7	44.70%	50.85%	0.0378%	OK
8	910.00					

Table 7
Strain Calculation
Section 3-3'

Point No.	Initial Elevation (ft)	Distance (ft)	Initial Grade (%)	Final Grade (%)	Δε	Allowable Strain 0.1%
3 A	745.79					
		144.24	2.49%	2.54%	0.0003%	OK
3 B	742.2					
		130.45	2.42%	2.65%	0.0018%	OK
3 C	739.04					
		320.67	2.33%	2.31%	0.0001%	OK
3 D	731.57					
		266.92	2.20%	2.43%	0.0009%	OK
3 D_1	725.37					
		Not connected with same slope				
3 D_2	734.00					
		Not connected with same slope				
3 D_3	725.27					
		63.73	1.96%	2.10%	0.0022%	OK
3 E	726.61					
		396.01	2.46%	2.45%	0.0000%	OK
3 F	736.35					
		Not connected with same slope				
8	837.27					

89-977 DR REV. 6/8/90

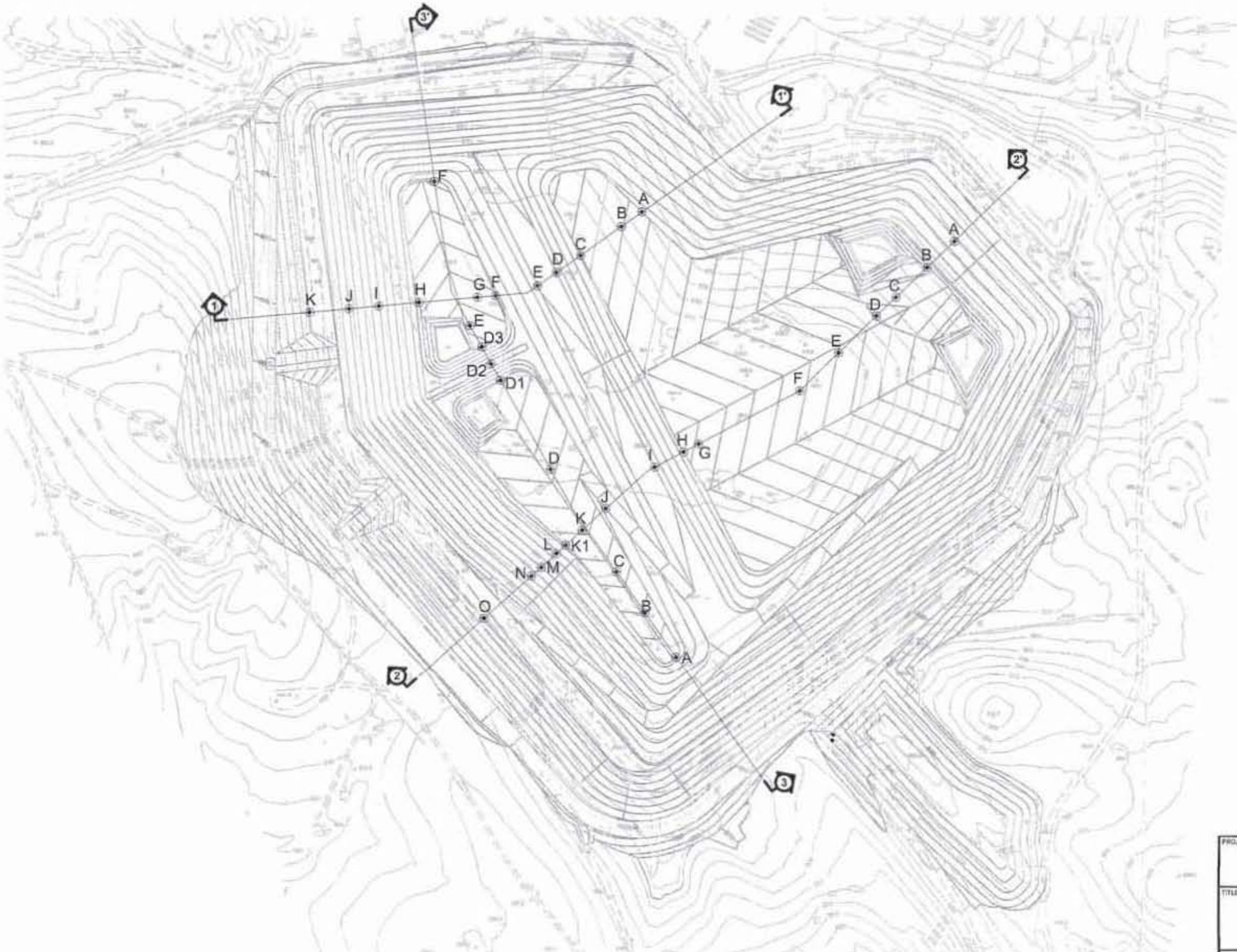
ATTACHMENT 1

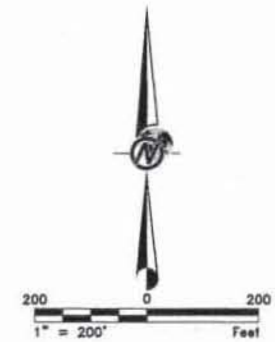
FIGURE 3.1

SITE GEOLOGIC AND EXPLORATION MAP

LANDFILL UNIT B-18
KETTLEMAN HILLS FACILITY

ENVIRONMENTAL SOLUTIONS, INC.





NOTE:
SETTLEMENT CALCULATION POINTS BASED ON CHANGES INGRADE AND/OR GEOLOGIC CONTACTS (BASED ON E.S.I., 1990) AS SHOWN ON FIGURE 3.1

PROJECT

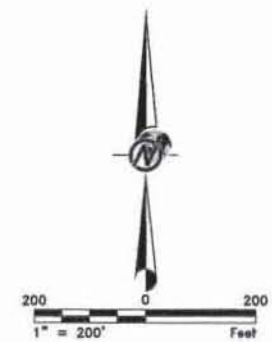
WASTE MANAGEMENT, INC.
LANDFILL UNIT B-18
KETTLEMAN HILLS FACILITY

TITLE

SETTLEMENT CROSS-SECTION LOCATIONS (BASE GRADES)

Golder Associates

PROJECT No.			FILE No. SETTL SECTIONS	
DESIGN	KK	04/08	SCALE	REV. A
CADD	FFG	10/08	DWG 1	
CHECK	EH	05/08		
REVIEW	SS	11/08		



PROJECT

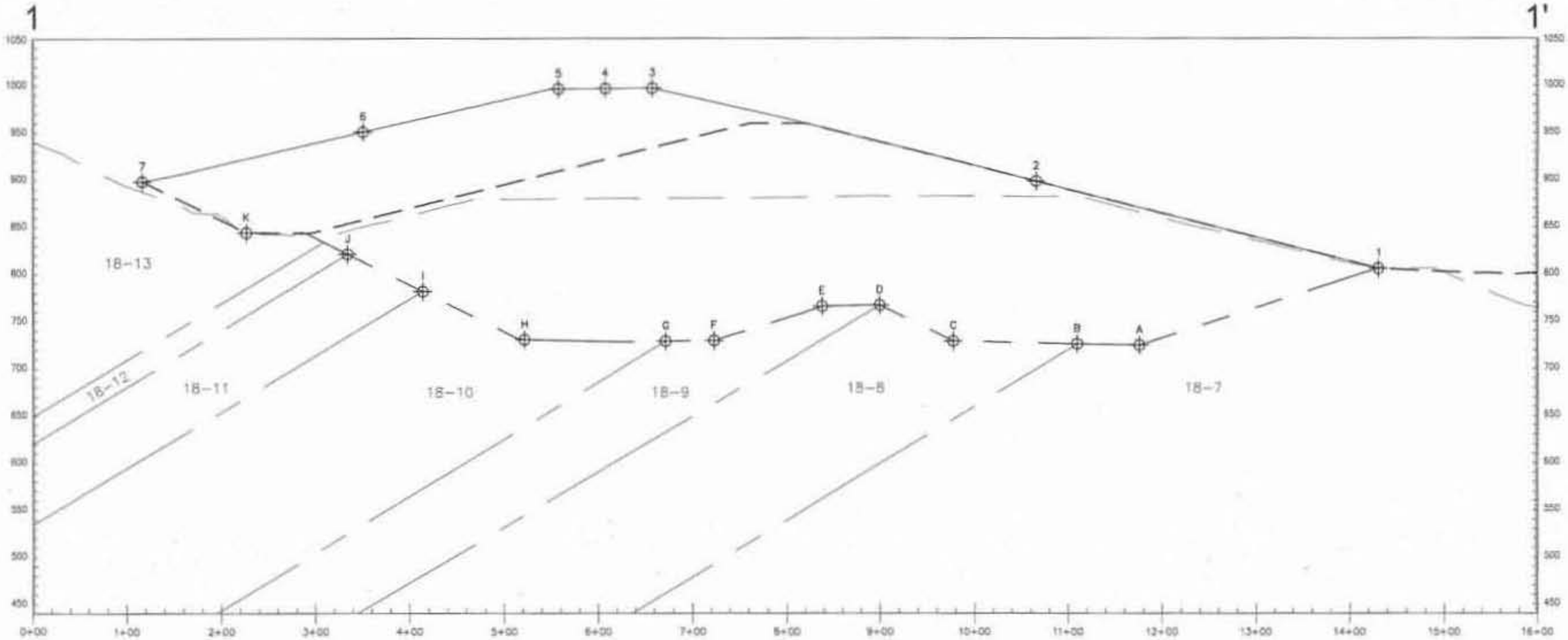
WASTE MANAGEMENT, INC.
LANDFILL UNIT B-18
KETTLEMAN HILLS FACILITY

TITLE

SETTLEMENT CROSS-SECTION LOCATIONS (CLOSURE GRADES)

Golder Associates

PROJECT No.			FILE No. SETTL SECTIONS
DESIGN	KK	04/14/08	SCALE AS SHOWN REV. A
CADD	LAD	04/18/08	
CHECK			**DWG 2**
REVIEW			



LEGEND

- 2008 DESIGN (FINAL CLOSURE)
- 1990 DESIGN (ESI)
- EXISTING GROUND (MARCH 2008)
- ASBUILT SUBGRADE
- EXISTING SUBSURFACE GEOLOGY
- B — SUBGRADE ANALYSIS POINT
- 2 — COVER ANALYSIS STATION

PROJECT

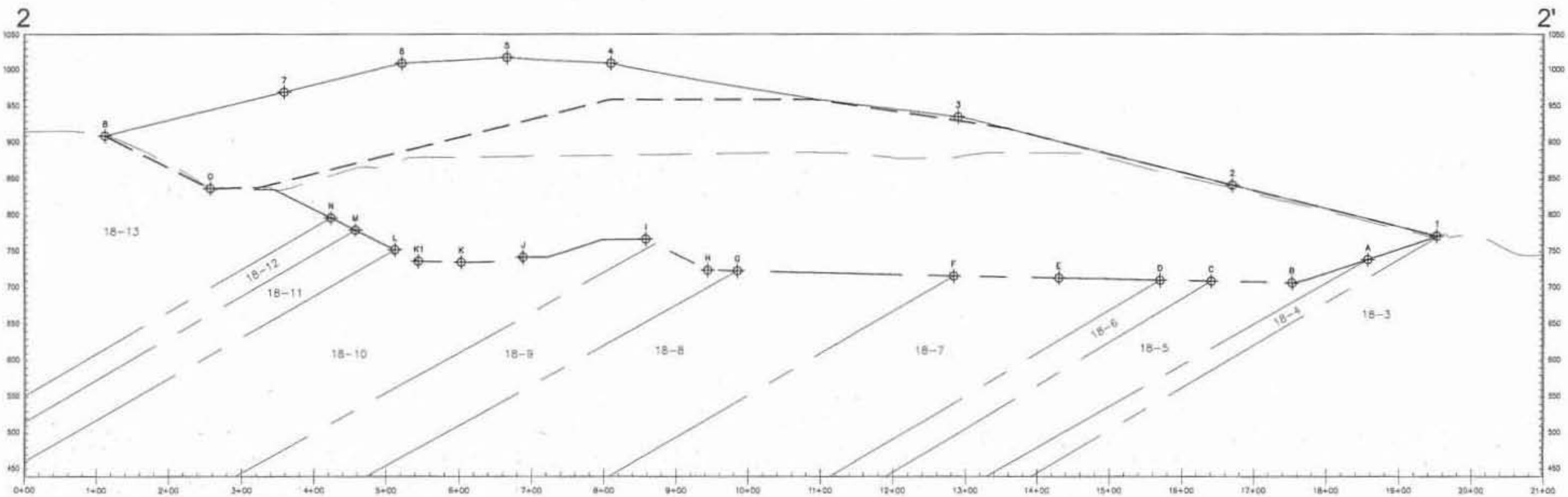
WASTE MANAGEMENT, INC.
LANDFILL UNIT B-18
KETTLEMAN HILLS FACILITY

TITLE

SETTLEMENT CROSS-SECTION 1-1'

Golder Associates

DWG 3



LEGEND

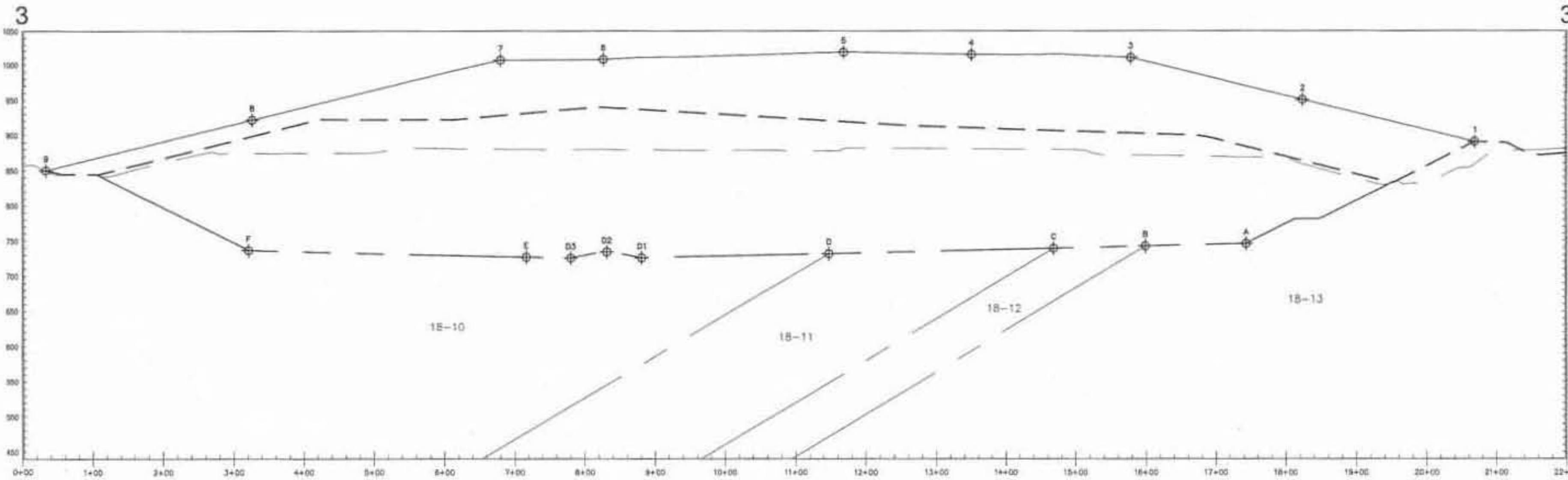
2008 DESIGN (FINAL CLOSURE)
1990 DESIGN (ESI)
EXISTING GROUND (MARCH 2008)
ASBUILT SUBGRADE
EXISTING SUBSURFACE GEOLOGY
B — SUBGRADE ANALYSIS POINT
2 — COVER ANALYSIS STATION

WASTE MANAGEMENT
LANDFILL UNIT B-18
KETTLEMAN HILLS FACILITY

SETTLEMENT CROSS-SECTION 2-2'

Golder Associates

DWG 4



LEGEND

Symbol	Description
solid line	2008 DESIGN (FINAL CLOSURE)
long dashes	1990 DESIGN (ESI)
light dashes	EXISTING GROUND (MARCH 2008)
dashed line	ASBUILT SUBGRADE
thin line	EXISTING SUBSURFACE GEOLOGY
B ⊕	SUBGRADE ANALYSIS POINT
2 ⊕	COVER ANALYSIS STATION

PROJECT

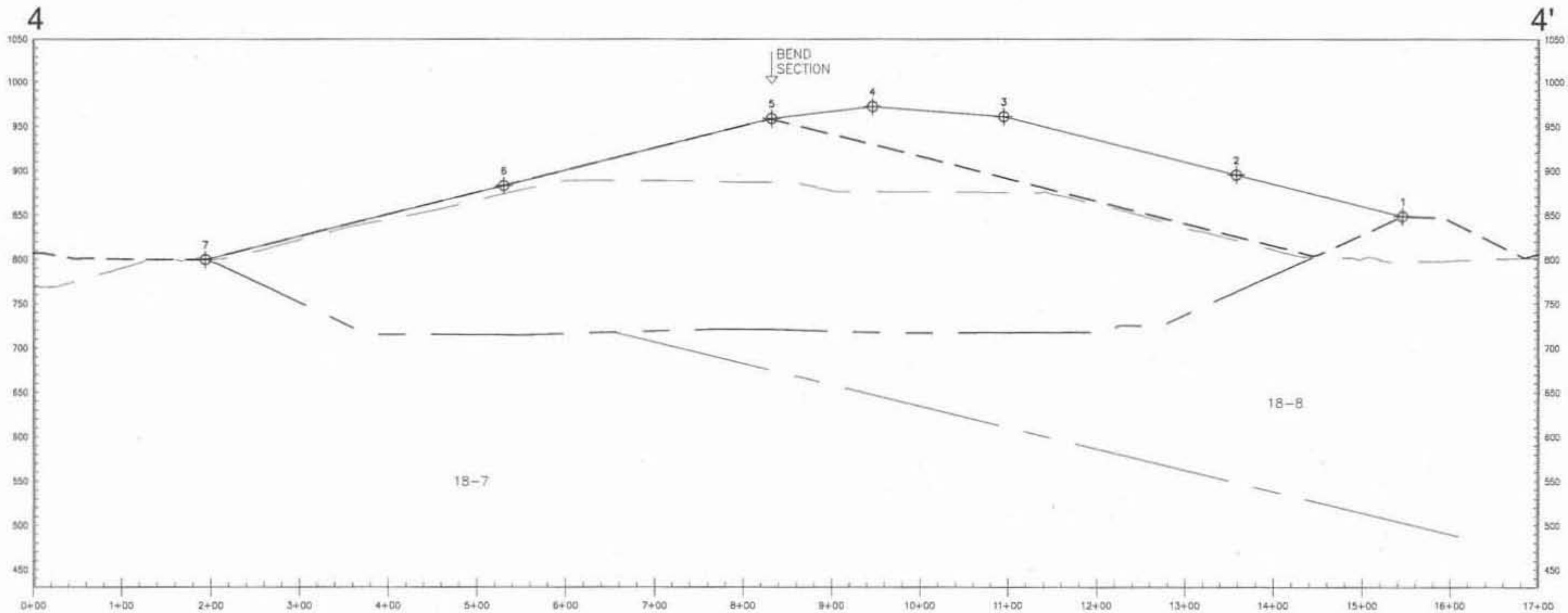
WASTE MANAGEMENT
LANDFILL UNIT B-18
KETTLEMAN HILLS FACILITY

TITLE

SETTLEMENT CROSS-SECTION 3-3'

Golder Associates

PROJECT No.			FILE No. SETTL SECTIONS	
DESIGN	KK	04/08	SCALE AS SHOWN	REV. A
CADD	FFG	04/08	**DWG 5**	
CHECK	EH	05/08		
REVIEW	SS	11/08		



LEGEND

2008 DESIGN (FINAL CLOSURE)
1990 DESIGN (ESI)
EXISTING GROUND (MARCH 2008)
ASBUILT SUBGRADE
EXISTING SUBSURFACE GEOLOGY
B — SUBGRADE ANALYSIS POINT
2 — COVER ANALYSIS STATION

PROJECT
WASTE MANAGEMENT
LANDFILL UNIT B-18
KETTLEMAN HILLS FACILITY

TITLE
SETTLEMENT CROSS-SECTION 4-4'

Golder Associates

DWG 6

APPENDIX G.2
CLAY LINER RATE OF CONSOLIDATION

ENVIRONMENTAL SOLUTIONS, INC.

By GSC Date 8/1/90 Subject CONSOLIDATION OF BOTTOM CLAY LINER FOR KETTLEMAN HILL B-18 LANDFILL Sheet No. 1 of 6

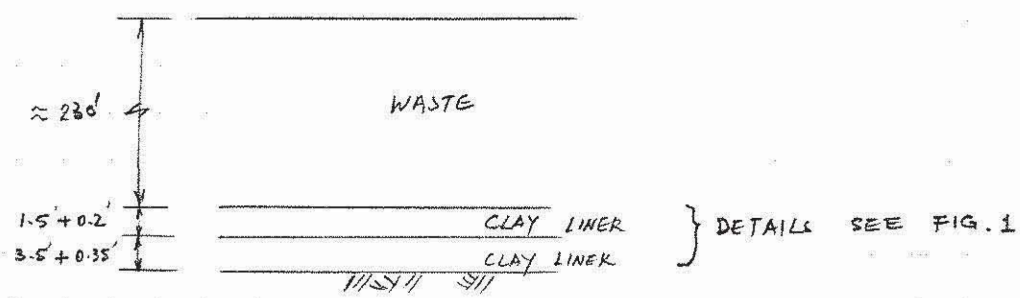
Chkd. By [illegible] Date 8/15/90 Proj. No. 89-977

OBJECTIVE : TO EVALUATE THE CONSOLIDATION CHARACTERISTIC OF BOTTOM CLAY LINER FOR STRENGHT EVAVATION

REF : (1) LAMBE & WHITEMAN (1969) "SOIL MECHANICS" PUBLISHED BY JOHN WILEY & SONS, INC. P408-410

(2) DEP. OF NAVY, NAVAL FACILITIES ENGINEERING COMMAND (1971) "DESIGN MANUAL, DM-7" MARCH

PHYSICAL PROPERTIES :



THICKNESS OF UPPER CLAY LINER : 1.5' + 0.2' (TOLERANCE)

LOWER CLAY LINER : 3.5' + 0.35' (TOLERANCE)

DRAINAGE PATH = ONE WAY DOWNWARD

CONSOLIDATION COEFFICIENT C_v = BASED ON CONSOLIDATION TESTS RESULTS ON TWO COMPACTED CLAY FROM KETTLEMAN HILL BORROW AREA (SEE FIGS 2 & 3)

BASED ON PRESENT INCOMING WASTE RATE OF 500,000 CY/YR

FILL OPERATION PERIOD = 16 yrs to 19 yrs TO FULL HEIGHT FOR TOTAL VOLUME OF 9.7×10^6 C.Y.

ENVIRONMENTAL SOLUTIONS, INC.

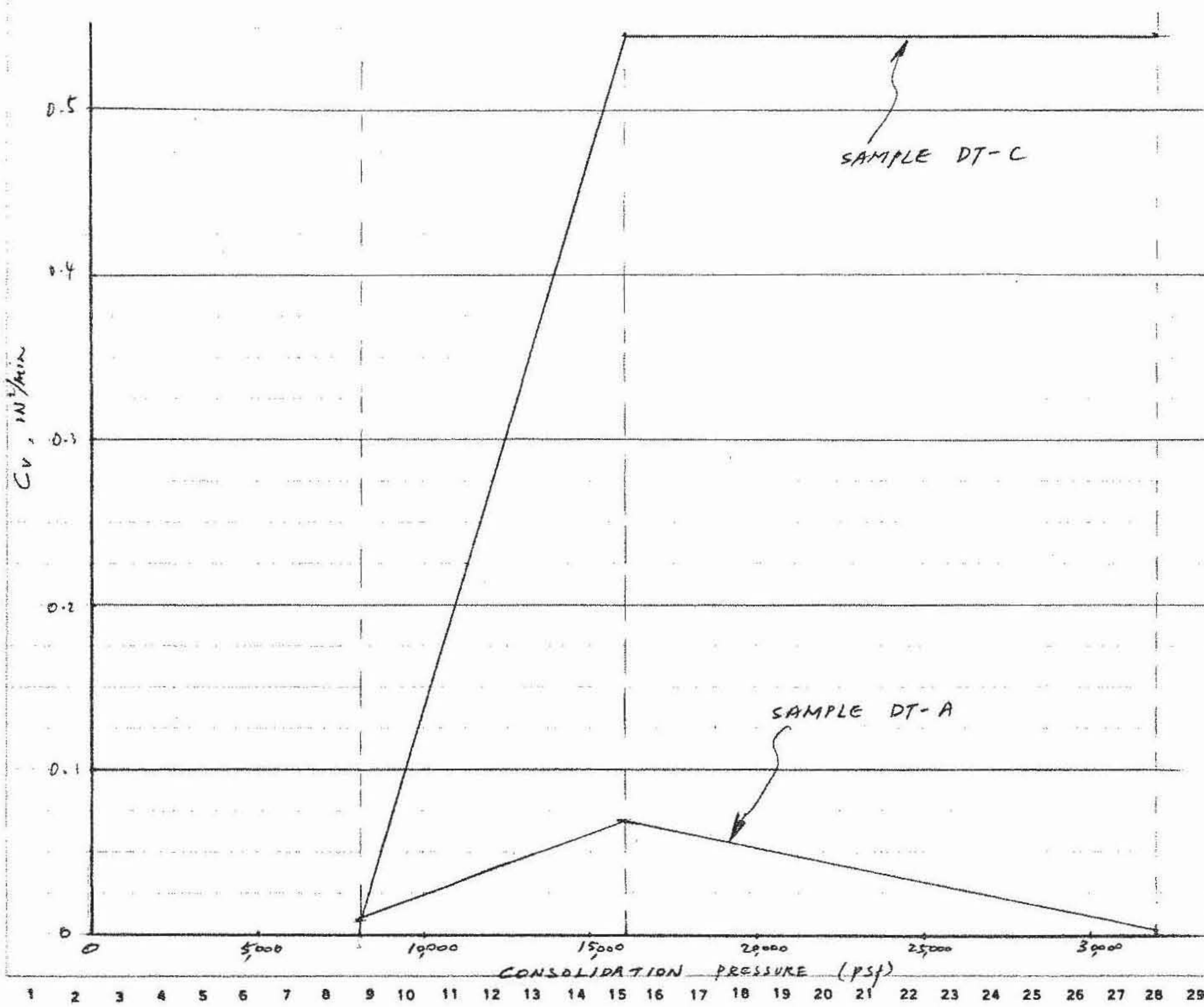
By GSC Date 8/1/90 Subject CONSOLIDATION OF BOTTOM CLAY LINER FOR KETTLEMAN HILL B-18 LANDFILL Sheet No. 2 of ____

Chkd. By Tpi Date 8/15/90 Proj. No. 89-977

FROM CONSOLIDATION TEST RESULTS
(SEE ATTACHED FIGS. 2 & 3)

H = LENGTH OF DRAIN PATH FOR SAMPLE = $\frac{1.0}{2}$ i

SAMPLE No.	CONSOLIDATION PRESSURE (psf)	D_0 (IN)	D_{100} (IN)	$D_{50} = \frac{D_0 + D_{100}}{2}$ (IN)	t_{50} (MIN)	$C_v = \frac{0.197 (H)^2}{t_{50}}$ IN²/min
DT-C, B-1	8000	0.0036	0.0072	0.0054	5	0.00985
8'	16000	0.00	0.0240	0.0126	0.09	0.547
	32000	0.00	0.0442	0.0221	0.09	0.547
DT-A, B-2	8000	0.0020	0.0076	0.0048	4	0.0123
5'	16000	0.0	0.0286	0.0143	0.7	0.0704
	32000	0.0	0.046	0.023	23	0.00214



ENVIRONMENTAL SOLUTIONS, INC.

By GSC Date 8/2/90 Subject CONSOLIDATION Sheet No. 3 of ____
Chkd. By [illegible] Date 8/15/90 KETTLEMAN HILL B-18 LANDFILL Proj. No. 89-977

BASED ON THE TEST RESULTS, A CONSERVATIVE VALUE OF $C_V = 0.0021\ IN^2/MIN$ IS USED FOR THE FOLLOWING CALCULATIONS.

UPPER CLAY LINER

$$T_o = \frac{C_v t_o}{H^2} \quad \text{----- (REF 2)}$$

WHERE T_o = TIME FACTOR AT END OF CONSTRUCTION
t_o = END OF LANDFILL OPERATION (USE 16 yrs)
H = THICKNESS OF CLAY LAYER = 1.7'

$$T_o = \frac{0.0021 \times 16 \times (365 \times 24 \times 60)}{(1.7 \times 12)^2} = 42.3$$

DEGREE OF CONSOLIDATION $U > 96\%$ —— SEE REF(2), FIG. 6.b
DURING AND AT END OF LANDFILL OPERATION (SEE ATTACHMENT

LOWER CLAY LINER

$$T_o = \frac{0.0021 \times 16 \times (365 \times 24 \times 60)}{(3.9 \times 12)^2} = 8.1$$

DEGREE OF CONSOLIDATION $U = 96\%$ —— SEE REF (2)
DURING AND AT END OF LANDFILL OPERATION FIG. 6-6
(SEE ATTACHMENT 1)

$T \approx 10$ when $U = 100\%$

$$t = \frac{TH^2}{C_v} = \frac{10 \times (3.9 \times 12)^2}{0.0021} \times \frac{1}{365 \times 24 \times 60} = 19.8 \text{ yrs}$$

∴ THE LOWER LAYER OF CLAY LINER IS EXPECTED TO REACHED 100% CONSOLIDATION IN 3 YEARS AFTER THE FINAL FILL OPERATION.

ENVIRONMENTAL SOLUTIONS, INC.

CHECK CONSOLIDATION OF CLAY LINER BENEATH RISER

THE THICKEST CLAY LINER BENEATH THE RISER WILL BE 5.0' + 0.35' (TOLERANCE) FOR THE LOWER CLAY LAYER.

$$T_o = \frac{0.0021 \times 16 \times (365 \times 24 \times 60)}{(5.35 \times 12)^2}$$

$$= 4.28$$

SEE REF. (2) FIG. 6-6 (SEE ATTACHMENT 1)
THE LOWEST DEGREE OF CONSOLIDATION WOULD BE NEAR THE END OF LANDFILL OPERATION AND WOULD HAVE AT LEAST ABOUT 92% DEGREE OF CONSOLIDATION AND REACH 100% DEGREE CONSOLIDATION IN WITHIN A FEW YEARS

TIME TO REACH 100% CONSOLIDATION $T = 6$ — Ref. (2)

$$t = \frac{TH^2}{C_v} = \frac{6 \times (5.35 \times 12)^2}{0.0021} \times \frac{1}{365 \times 24 \times 60}$$

$$= 22.3 \text{ yrs}$$

THAT IS $(22.3 - 16)$ yrs $= 6.3$ yrs AFTER CONSTRUCTION

ENVIRONMENTAL SOLUTIONS, INC.

By GSC Date 8/2/90 Subject CONSOLIDATION Sheet No. 5 of ____

Chkd. By [illegible] Date 8/15/90 KETTLEMAN HILL Proj. No. 89-977

B-18 LANDFILL

EVALUATE PHASE I LANDFILL OPERATION V.S. CONSOLIDATION

PHASE I OPERATION PERIOD ABOUT TWO YEARS

$$T_o = \frac{0.0021 \times 2 \times (365 \times 24 \times 60)}{(5.35 \times 12)^2}$$

$$= 0.53$$

REF (2) FIG. 6-6

AT THE END OF LANDFILL OPERATION, THE DEGREE OF CONSOLIDATION WOULD BE APPROXIMATELY 55% FOR THE OVERALL THICKNESS OF CLAY

FOR $U = 55\%$ REF (1) FIG. 27.3

$T \approx 0.25$

FOR $T \approx 0.25$ REF (1) FIG 27.2

$z = 1$

U (AT HDPE/CLAY INTERFACE) $\approx 30\%$ CONSOLIDATION AT INTERFACE

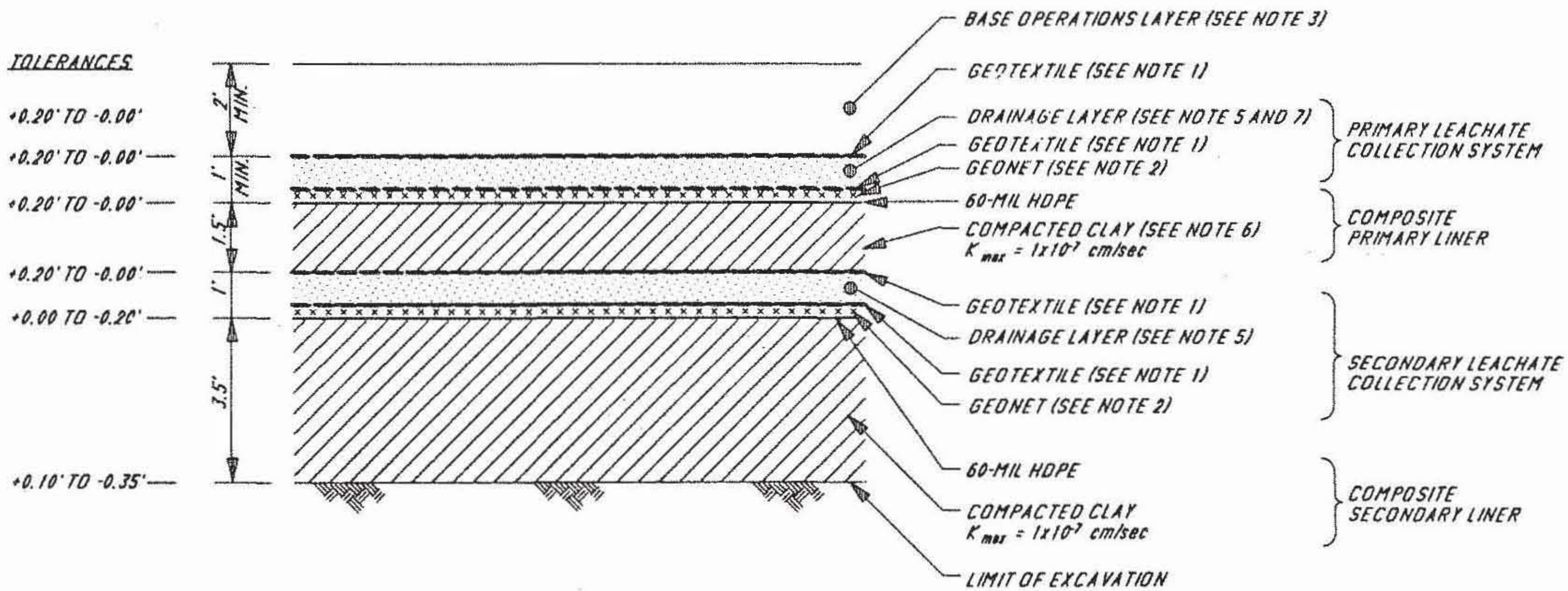
CONCLUSION:

(1.) CONSOLIDATION HAS REACHED ABOUT 96% FOR THE TWO CLAY LINERS AT THE BOTTOM OF THE LANDFILL WHEN THE FINAL LANDFILL OPERATION IS COMPLETED. THE DEGREE OF CONSOLIDATION IS FOUND TO BE AT LEAST 96% THROUGH OUT THE OPERATION PERIOD. BECAUSE THIS DEGREE OF CONSOLIDATION IS CLOSE TO THE 100% MARK, THE CLAYS ARE PRACTICALLY FULLY CONCOLIDATED AND THE CLAY STRENGTH COULD BE ESTIMATED FROM THE CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION RESUTS.

ENVIRONMENTAL SOLUTIONS, INC.

By GSC Date 8/2/90 Subject CONSOLIDATION Sheet No. 6 of ____
Chkd. By [illegible] Date 8/15/90 Proj. No. 89-917

(2) BASED ON CONSOLIDATION EVALUATION FOR PHASE I FILL OPERATION, THE LOWEST DEGREE OF CONSOLIDATION AT THE INTERFACE OF THE CLAY LINER AND THE HDPE IS ABOUT 30% AT THE END OF PHASE I OPERATION. THEREFORE, THE STRENGTH OF THE CLAY LINER SHOULD BE ESTIMATED FROM THE UNCONSOLIDATED - UNDRAINED TRIAXIAL COMPRESSION TEST RESULTS FOR PHASE I STABILITY ANALYSIS. IT SHOULD ALSO BE REALIZED THAT THE STRENGTH FROM UU TEST OF AN UNSATURATED SAMPLE MAY BE HIGHER THAN THAT OF A SATURATED SAMPLE BECAUSE OF CAPILLARY ACTION. BASED ON THE UU TEST RESULTS, THE STRENGTH OF RECOMPACTED CLAY WAS REPORTED TO BE $\phi = 8^\circ$ & $C = 3600$ psf. IN CONSIDERATION OF THE SATURATED CONDITION, THE ϕ WAS NOT INCLUDED IN THE STRENGTH PAREMETER IN ANALYZING THE STABILITY OF THE PHASE I LANDFILL.



BASE LINER

FIG. 1

7/15 8-15-90

8-15-90

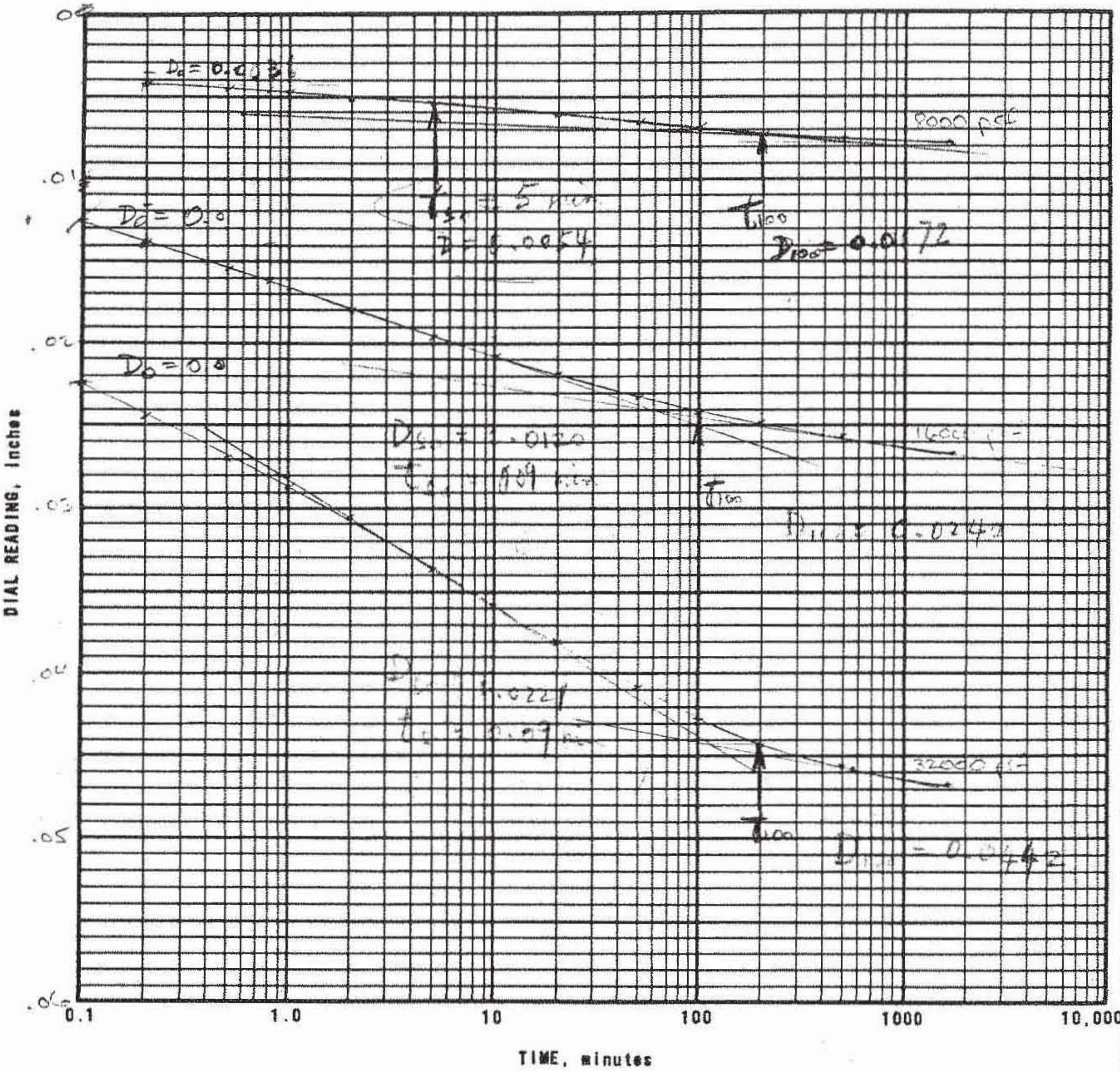


FIG. 2

DT-C, B-1, 8'

WAHLER ASSOCIATES	Kettleman	CONSOLIDATION TEST TIME – COMPRESSION CURVES		
		PROJECT NO.	DATE	FIGURE NO.
	PALO ALTO • [redacted] • CALIF.	ESK 101A	7/90	

VPi
8-15-90

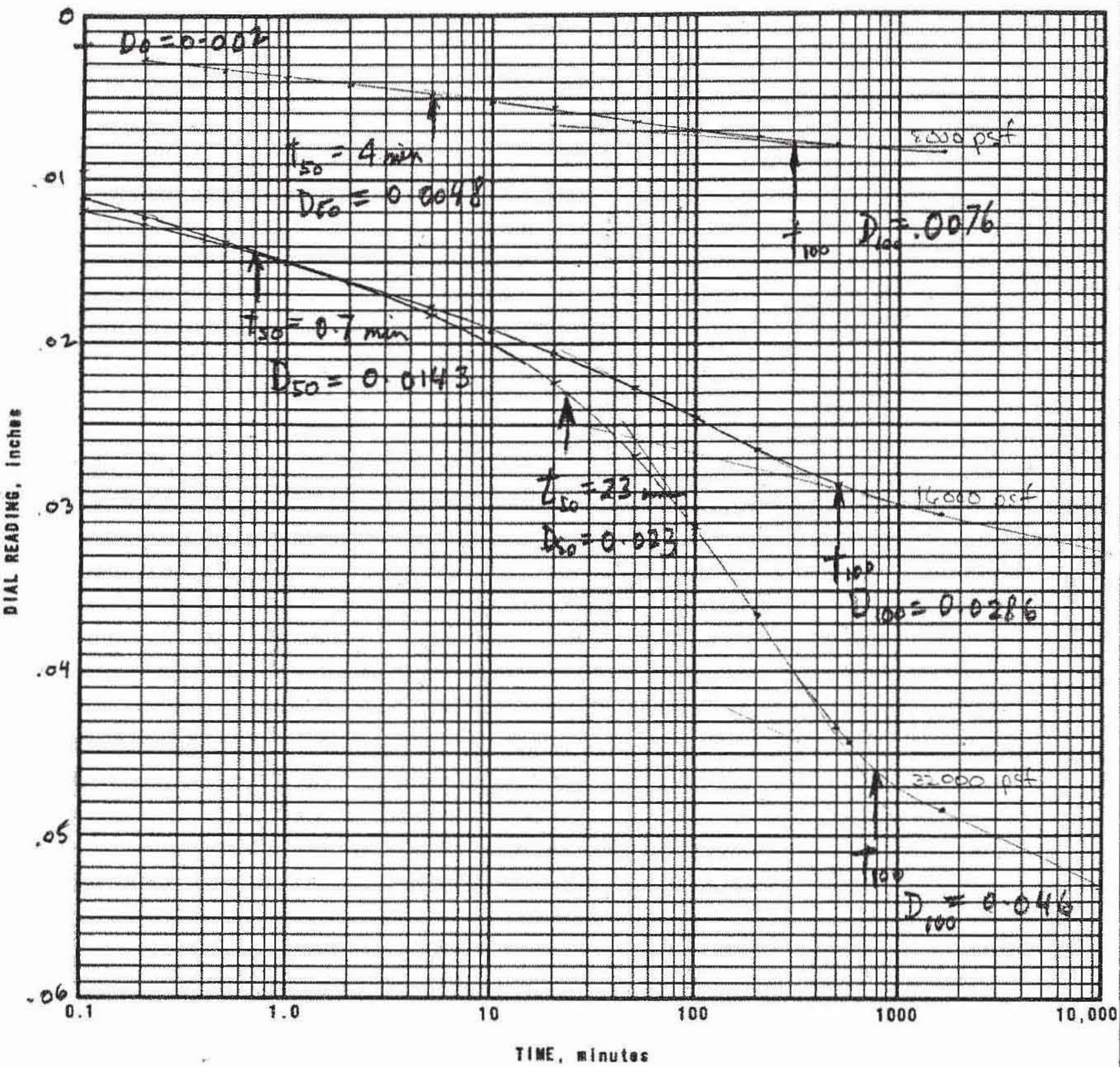


Fig. 3

DT - A, B - 2, 5'

WAHLER ASSOCIATES	Kettleman	CONSOLIDATION TEST TIME - COMPRESSION CURVES	
PALO ALTO • [redacted] • CALIF.	PROJECT NO. ESK 101A	DATE 7 90	FIGURE NO.

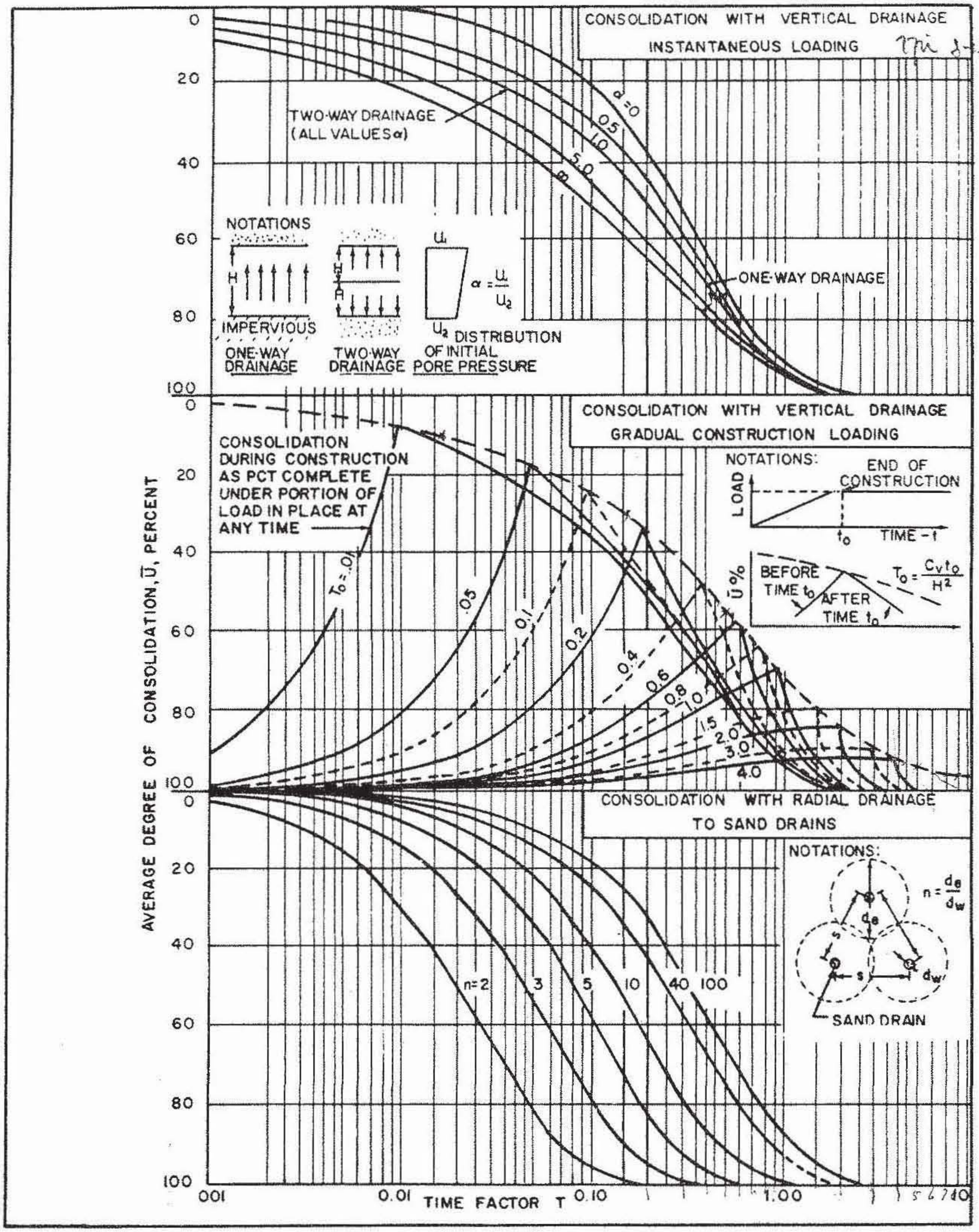


FIGURE 6-6
Time Factors for Consolidation Analysis

ATTACHMENT 1

REF: "SOIL MECHANICS" BY LAMBE

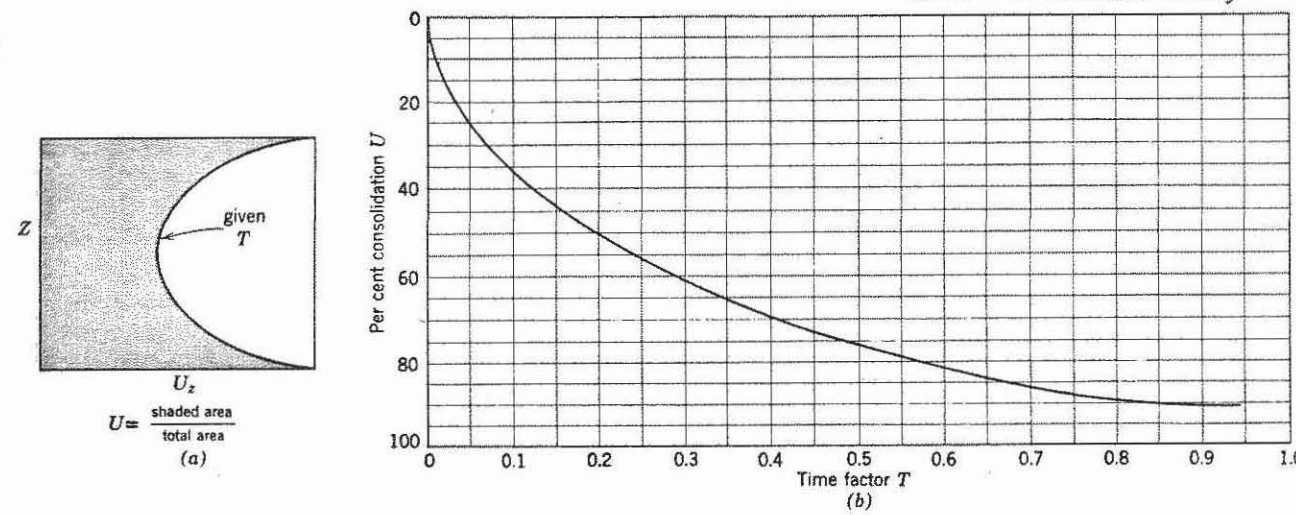


Fig. 27.3 Average consolidation ratio: linear initial excess pore pressure. (*a*) Graphical interpretation of average consolidation ratio. (*b*) *U* versus *T*.

value for c_v. This is generally done by observing the rate of compression of an undisturbed sample during an oedometer (or consolidation) test (see Sections 9.1 and 20.2).

Figure 27.4 shows a typical set of dial readings, showing change in thickness with time, obtained during one increment of load. The form of such actual time versus compression curves is similar to, but not exactly the same as, the theoretical curves predicted from consolidation theory. The following *fitting methods* are commonly used to determine c_v from such test results (Lambe, 1951).

Square root method. Extend a tangent to the straight-line portion of the observed curve back to intersect zero time and obtain the corrected zero point d_s. Through d_s draw a straight line having an inverse slope 1.15 times the tangent. Theoretically, this straight line should cut the observed compression-time curve at 90% compression. Thus the time to 90% compression is 12.3 minutes. From Fig. 27.3, the dimensionless time *T* for 90% compression is 0.848. Substituting these results, with *H* equal to the thickness of the sample per drainage surface (1.31 cm in this case) into Eq. 27.8*b*, c_v is determined to be 26.2×10^{-4} cm²/sec.

Log method. As shown in Fig. 27.4*b*, tangents are drawn to the two straight-line portions of the observed curve. The intersection of these curves defines the d_{100} point. The corrected zero point d_s is located by laying off above a point in the neighborhood of 0.1 minute a distance equal to the vertical distance between this point and one at a time which is four times greater. The 50% compression point is halfway between d_s and d_{100}, or at a time of 3.3 minutes. From the theoretical curve, $T = 0.197$ for 50% compression. Using Eq. 27.8b, c_v is then computed at 22.7×10^{-4} cm²/sec.

Discussion of results. Obviously, these fitting methods contain arbitrary steps that compensate for differences between actual and theoretical behavior. A correction for the initial point is usually required because of apparatus errors or the presence of a small amount of air in the specimen. An arbitrary determination of d_{90} or d_{100} is required because compression continues to occur even after excess pore pressures are dissipated. This *secondary compression* occurs because the mineral skeleton has time-dependent stress-strain properties (Chapter 20); the importance of secondary compression will be discussed in Section 27.7. The fitting methods have been developed to provide the best possible estimates for c_v. It is hardly surprising that the two methods yield somewhat different results. The square root method usually gives a larger value of c_v than does the log method, and this method is usually preferred.

In addition to the problems involved in evaluating c_v from a given increment, c_v varies from increment to increment and is different for loading and unloading. Figure 27.5 shows typical results. Moreover, c_v usually varies considerably among samples of the same soil.

Thus it is quite difficult to select a value of c_v for use in a particular engineering problem and hence it is difficult to predict accurately the rate of settlement or heave. Often the actual observed rate of settlement or heave of a structure is two to four times faster than the rate predicted on the basis of c_v as measured using undisturbed samples (e.g., see Bromwell and Lambe, 1968). Such differences arise partially because of the difficulties in measuring c_v, partially because of shortcomings in the linear theory of consolidation, and partially because of the two- and three-dimensional effects discussed in Section 27.6. Predictions of rate of consolidation are useful only to indicate in advance of construction the approximate time required for consolidation. If the actual rate of consolidation is critical to the design, as in certain stability problems where the excess

ATTACHMENT 2

Ref : "Soil Mechanics" By Lambe

equation applicable to numerous physical problems. In particular, the equations for transient heat flow are basically identical to these equations for consolidation, with temperature replacing excess pore pressure. Solutions have been obtained for many problems in heat flow involving a variety of initial and boundary conditions, and these solutions often may be used to considerable advantage in the study of consolidation.

27.2 SOLUTION FOR UNIFORM INITIAL EXCESS PORE PRESSURE

The simplest case of consolidation is the one-dimensional problem in which: (*a*) the total stress is constant with time, so that $\partial\sigma_v/\partial t = 0$; (*b*) the initial excess pore pressure is uniform with depth; and (*c*) there is drainage at both the top and bottom of the consolidating stratum. These conditions are met by the loading in Fig. 26.2 provided that the loading is applied in a time that is very small compared to the consolidation time so that literally no consolidation occurs before the loading is complete. The total vertical stress at any point will then be constant during the consolidation process.

For this problem, it is convenient to convert Eq. 27.4 by introducing nondimensional variables:

$$Z = \frac{z}{H} \qquad (27.8a)$$

$$T = \frac{c_v t}{H^2} \qquad (27.8b)$$

where z and Z are measured from the top of the consolidating stratum and H is *one-half* of the thickness of the consolidating stratum. (The reason for this choice of H will be apparent later.) The nondimensional time T is called the *time factor*. With these variables, Eq. 27.4 becomes

$$\frac{\partial^2 u_e}{\partial Z^2} = \frac{\partial u_e}{\partial T} \qquad (27.9)$$

We now need a solution to Eq. 27.9 satisfying the following conditions:

Initial condition at $t = 0$:

$$u_e = u_0 \text{ for } 0 \leq Z \leq 2$$

Boundary condition at all t:

$$u_e = 0 \text{ for } Z = 0 \text{ and } Z = 2$$

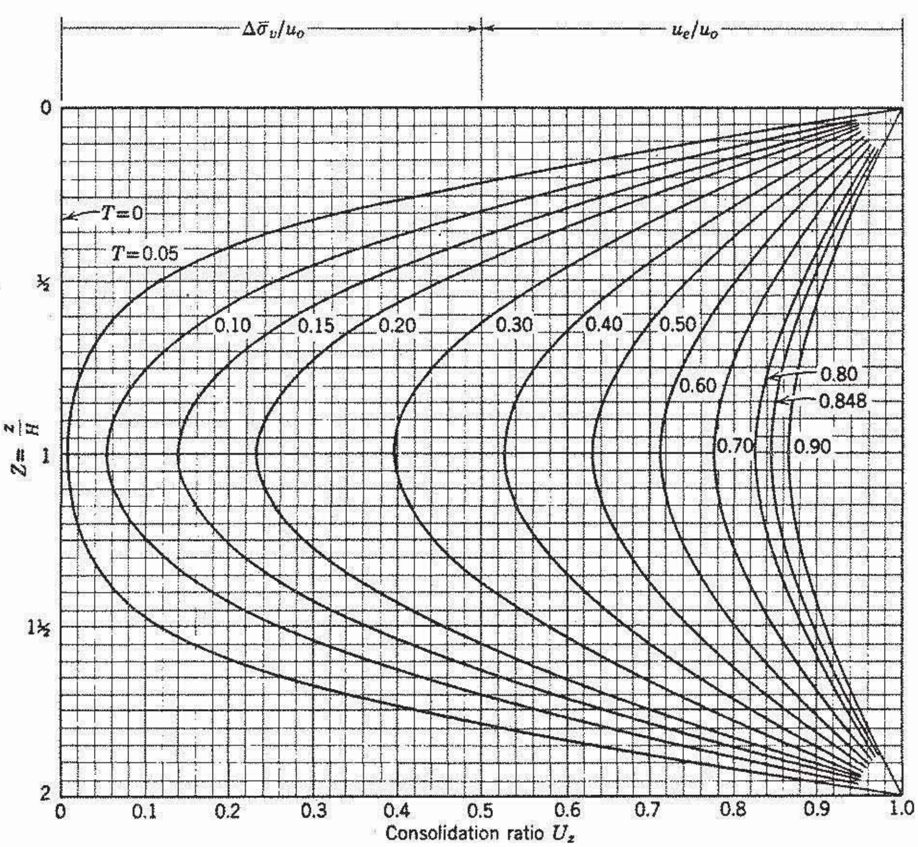


Fig. 27.2 Consolidation ratio as function of depth and time factor: uniform initial excess pore pressure.

ATTACHMENT 3

APPENDIX G.3

CLAY LINER CONSOLIDATION SETTLEMENT

Golder Associates	Kettleman Hills Facility – Landfill Unit B-18 Expansion Settlement of Clay Liner	
	Project No.: 083-91887	Made By: EH
	Date: 10/28/08	Checked By: RH
	Sheet: 1 of 2	Reviewed By:

Objective:

Estimate the additional settlement due to the increased waste loads from the Phase III expansion.

Reference:

Environmental Solutions Inc. (ESI) Engineering Report Settlement Calculations (Attached).

Discussion:

ESI previously calculated the settlement of the clay liner due to placement of 230 feet of waste. The expansion project will increase the waste height to approximately 300 feet. This additional load will result in further compression of the clay.

Calculation:

1) Primary consolidation settlement
   - The maximum load due to waste: Max. σ_v = 300' x 115pcf = 34.5 ksf
   - The consolidation settlement at 34.5 ksf is approximately 9.5% of the total thickness (see Figures 1 and 2).

Clay Liner	Primary	Secondary
Initial clay liner thickness	1.5'	3.5'
Consolidation settlement (9.5%)	0.14'	0.33'
Post Consolidation Thickness	1.36'	3.17'

2) Secondary consolidation settlement (or creep settlement)

   Secondary consolidation settlement will occur after the closure of the landfill. The secondary settlement can be computed using the following equation:

   $\Delta_s = C_\alpha(H_t)\mathrm{Log}(t_s/t_p)$

   Δ_s =secondary settlement (ft)

   C_α= coefficient of secondary compression, 0.005 per ESI

   H_t = initial thickness

   t_s = duration of secondary compression assuming to be 30 years post closure period.

   t_s = time to complete primary consolidation conservatively assumed to be 20 years (1994-2014) to fill landfill.

   Primary Clay Liner: Δ_s = 0.005 (1.36) Log(30/20) = 0.0012 ft

   Secondary Clay Liner: Δ_s = 0.005 (3.17) Log(30/20) = 0.0028 ft

3) Final Clay Liner Thickness

   Primary clay liner: 1.5'-0.14'-0.0012' = 1.36' > 1.0' OK

   Secondary liner: 3.5'-0.33'-0.0028' > 3.0' OK

4) Settlement for clay liner beneath vertical riser

Settlement of the clay liner beneath the vertical riser is estimated to increase by an additional 5% due to riser imposed loads.

Thus, settlement of the clay below the riser will be 9.5% + 5.0% = 14.5% of the original thickness. Secondary compression is considered to be negligible based on previous calculation.

Settlement in the secondary clay liner = 14.5% x 5' = 0.725'
The final secondary clay liner thickness is estimated to be 5'-0.725' ≅ 4.3' > 3' OK

Settlement in the primary clay liner = 14.5% x 3' = 0.44'
The final primary clay liner thickness is estimated to be 3'-0.44' ≅ 2.5' > 1' OK

ENVIRONMENTAL SOLUTIONS, INC.

By GSC Date 8/8/90 Subject SETTLEMENT OF CLAY LINER Sheet No. 1 of ___
Chkd. By [illegible] Date 8/9/90 Proj. No. 89-977

OBJECTIVE : TO ESTIMATE SETTLEMENT OF CLAY LINER FOR KETTLEMAN HILL B-18 LANDFILL BASE IN DETERMINING COMPLIANCE WITH MINIMIUM THICKNESS (3') REQUIREMENT FOR BOTTOM CLAY L

REFERENCE : (1) LAMBE & WHITEMAN (1969) "SOIL MECHANICS" PUBLISHED BY JOHN WILEY & SONS, INC.

(2) DEPT. OF NAVY, NAVAL FACILITIES ENGINEERING COMMAND (1971) "DESIGN MANUAL, DM-7" MARCH.

DISCUSSION : TOTAL SETTLEMENT OF BASE CLAY LINER WILL INCLUDE PRIMARY AND SECONDARY SETTLEMENT. THE PRIMARY SETTLEMENT IS ASSOCIATED WITH THE CONSOLIDATION SETTLEMENT AND THE SECONDARY SETTLEMENT IS ASSOCIATED WITH THE CREEP MOVEMENT AFTER THE COMPLETION OF PRIMARY SETTLEMENT OR CONSOLIDATION.

$$\Delta_T = \Delta_p + \Delta_s$$

WHERE Δ_T = TOTAL SETTLEMENT
Δ_p = PRIMARY SETTLEMENT DUE TO CONSOLIDATION
Δ_s = SECONDARY SETTLEMENT DUE TO CREEP AFTER Δ_p

MAX. FILL (OVERBURDEN PRESSURE) AT COMPLETION OF LANDFILL OPERATION IS ESTIMATED TO BE APPROXIMATELY 210-FEET OF WASTE ABOVE THE LINER SYSTEM.

$$\text{Max. } \sigma_v = 230' \times 115 \text{ pcf} = 26450 \text{ psf or } 26.4 \text{ KSF}$$

ENVIRONMENTAL SOLUTIONS, INC.

By GSC Date 8/3/90 Subject SETTLEMENT OF CLAY LINER Sheet No. 2 of
Chkd. By [illegible] Date 8/16/90 Proj. No. 89-577

BASED ON CONSOLIDATION TEST RESULTS ON COMPACTED CLAY SAMPLES FROM CLAY BORROW MATERIAL AT THE SITE. FOR MAX. σ_v = 24.2 KSF. THE CONSOLIDATION SETTLEMENT IS ESTIMATED TO BE APPROXIMATELY 7% OF THE TOTAL THICKNESS OF CLAY CONCERNED. (SEE ATTACHED FIGS. 1 & 2)

	PRIMARY	SECONDARY
INITIAL CLAY LINER THICKNESS	1.5'	3.5'
CONSOLIDATION SETTLEMENT Δ_p	1.5'x0.07 = 0.105' = 1.26"	3.5'x0.07 = 0.245' = 2.94"

HOWEVER, BASED ON THE CALCULATION ON CONSOLIDATION CHARACTERISTIC OF CLAY LINER FOR B-18 LANDFILL, IT WAS FOUND THAT AT LEAST 96% OF THE CONSOLIDATION WILL BE COMPLETED AT THE END OF THE FINAL LANDFILL OPERATION THEREFORE, SETTLEMENT AFTER THE FINAL LANDFILL CLOSURE WILL BE MAINLY FROM THE SECONDARY SETTLEMENT OR CREEP SETTLEMENT. THE SECONDARY SETTLEMENT CAN BE COMPUTED USING THE FOLLOWING EQUATION:

$$\Delta_s = C_\alpha (H_t) \log \frac{t_{sec}}{t_p} \qquad \text{(REF 2)}$$

WHERE Δ_s = SETTLEMENT FROM SECONDARY COMPRES
C_α = COEFFICIENT OF SECONDARY COMPRESSION
H_t = INITIAL THICKNESS OF COMPRESSIBLE STRATUM
t_{sec} = USEFUL LIFE OF STRUCTURE.
t_p = TIME TO COMPLETION OF PRIMARY CONSOLIDATION

ENVIRONMENTAL SOLUTIONS, INC.

By GSC Date 8/3/90 Subject SETTLEMENT OF CLAY LINER Sheet No. 3 of ____

Chkd. By [illegible] Date 8/3/90 Proj. No. ____

REF. 2 FIGURE 3.5 (SEE ATTACHMENT 1)

FOR COMPLETELY REMOLDED SAMPLES USING w% ≈ 28% (Fig. 1 & 2)

$C_\alpha = 0.003$ TO 0.005

BASED ON LAB RESULTS FROM LOG. TIME CURVE OF THE CONSOLIDATION TEST (SEE FIGS. 3 & 4)

$C_\alpha = 0.0015$ TO 0.006 FOR APPROPRIATE PRESSURES

USE $C_\alpha = 0.005$ FOR ESTIMATE

BASED ON CALCULATION OF CONSOLIDATION BEHAVIOR OF CLAY LINER, THE CONSOLIDATION SETTLEMENT OF CLAY LINER GENERALLY COMPLETE AT ABOUT 2 TO 3 YEARS AFTER THE FINAL LANDFILL CLOSURE. THEREFORE SECONDARY SETTLEMENT COMMENCE AFTER THAT. THE SETTLEMENT DURING THE POST-CLOSURE PERIOD :

SECONDARY SETTLEMENT FOR CLAY LINER AT LANDFILL BOTTOM

PRIMARY CLAY LINER (REDUNDANT) $= 0.005\,(1.5 - 0.105)\log\frac{30}{18}$ $= 0.0015'$	SECONDARY CLAY LINER $= 0.005\,(3.5 - 0.245)\log\frac{30}{18}$ $= 0.0036'$
FINAL THICKNESS FOR : PRIMARY CLAY LINER (REDUNDANT) $= 1.5 - 0.105 - 0.0015$ $= 1.39'$	SECONDARY CLAY LINER $= 3.5 - 0.245 - 0.0036$ $= 3.25'$

* CHECK SETTLEMENT FOR CLAY LINER BENEATH VERTICAL RISER

REF. RISER BEARING CAPACITY COMPUTATION, PAGE 3 OF 4

PRIMARY SETTLEMENT DUE TO RISER IMPOSED LOAD = 5% OF THICKNESS

	PRIMARY CLAY LINER	SECONDARY CLAY LINER
TOTAL PRIMARY SETTLEMENT	$(0.07 + 0.005) \times 3 = 0.225'$	$(0.07 + 0.005) \times 5 = 0.375'$
SECONDARY SETTLEMENT	$0.005\,(3 - 0.225)\log\frac{30}{18} = 0.0031'$	$0.005\,(5 - 0.375)\log\frac{30}{18} = 0.0051'$
TOTAL	$= 0.2281'$	$= 0.3801'$
FINAL THICKN	$(3 - 0.2281') = 2.77'$	$(5 - 0.3801) = 4.42'$

ENVIRONMENTAL SOLUTIONS, INC.

By GSC Date 8/8/90 Subject SETTLEMENT OF CLAY LINER Sheet No. 4 of ____
Chkd. By [initials] Date 8/16/90 Proj. No. 89-977

CONCULSION :

1. BASED ON THE ABOVE CALCULATIONS, AT THE LANDFILL BASE, THE TOTAL SETTLEMENT OF THE SECONDARY CLAY LINER AT THE BOTTOM OF THE LANDFILL :

$$\Delta_T = \Delta_P + \Delta_S$$

$$= 0.245 + 0.0036$$

$$\simeq 0.25'$$

THEREFORE, THE 3.5-FOOT CLAY LAYER BENEATH THE LEACHATE COLLECTION SYSTEM WILL MAINTAIN A MINIMIUM THICKNESS REQUIREMENT OF 3-FOOT DURING THE POST-CLOSURE PERIOD.

2. TOTAL SETTLEMENT AT THE VERTICAL RISER BASE FOR THE SECONDARY CLAY LINER IS COMPUTED IN THE FOLLOWING :

$$\Delta_T = \Delta_P + \Delta_S$$

$$= 0.375' + 0.0051'$$

$$= 0.38'$$

THEREFOR, THE 5-FOOT SECONDARY LCRS CLAY LINER WILL MAINTAIN ITS THICKNESS OF NO LESS THAN 3-Foot FOR THE PRIMIUM.

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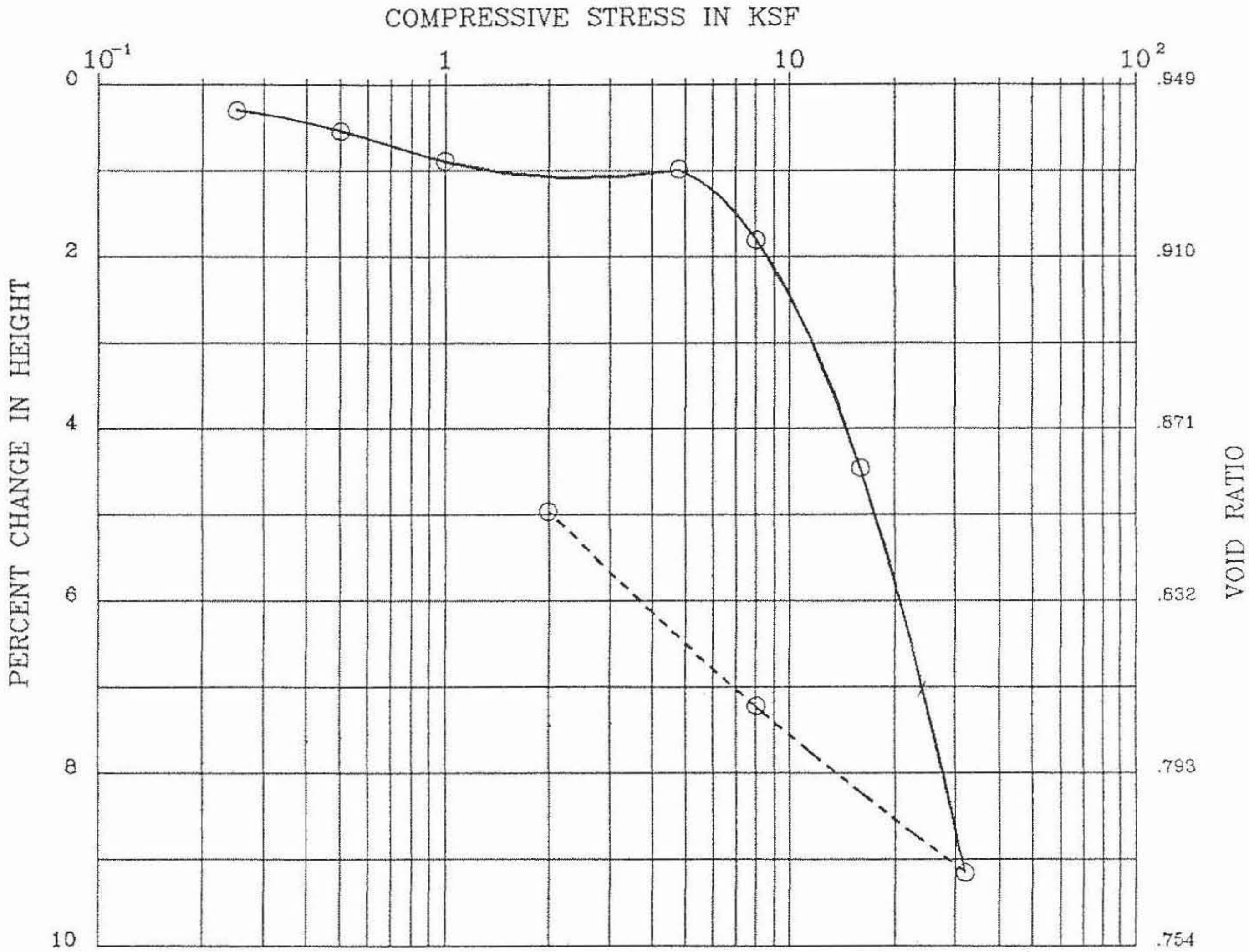


BORING	: DT–C, B–1		DESCRIPTION	: silty CLAYSTONE, yellow brn (CH)	
DEPTH (ft)	: 8		LIQUID LIMIT	: 76	
SPEC. GRAVITY	: 2.79		PLASTIC LIMIT	: 45	

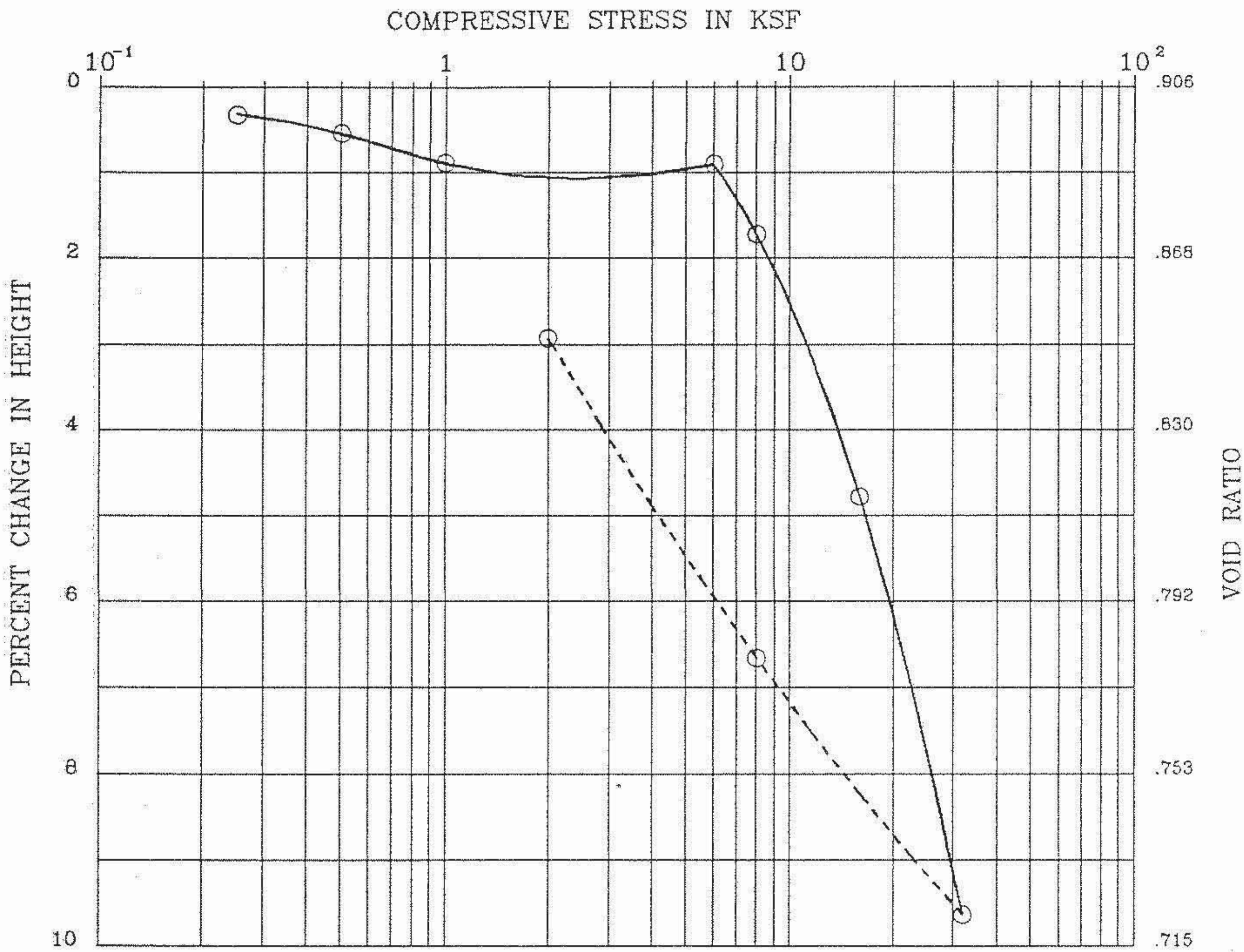
	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	PERCENT SATURATION	VOID RATIO
INITIAL	28.1	89.4	83	.949
FINAL	30.5	94.1	100	.852

FIG. 1

Remark : July 1990

Project ESK-101A	Kettleman	
Wahler Associates	CONSOLIDATION TEST	Figure No.

Vpi 8-16-90



BORING : DT-A, B-2
DEPTH (ft) : 5
SPEC. GRAVITY : 2.84

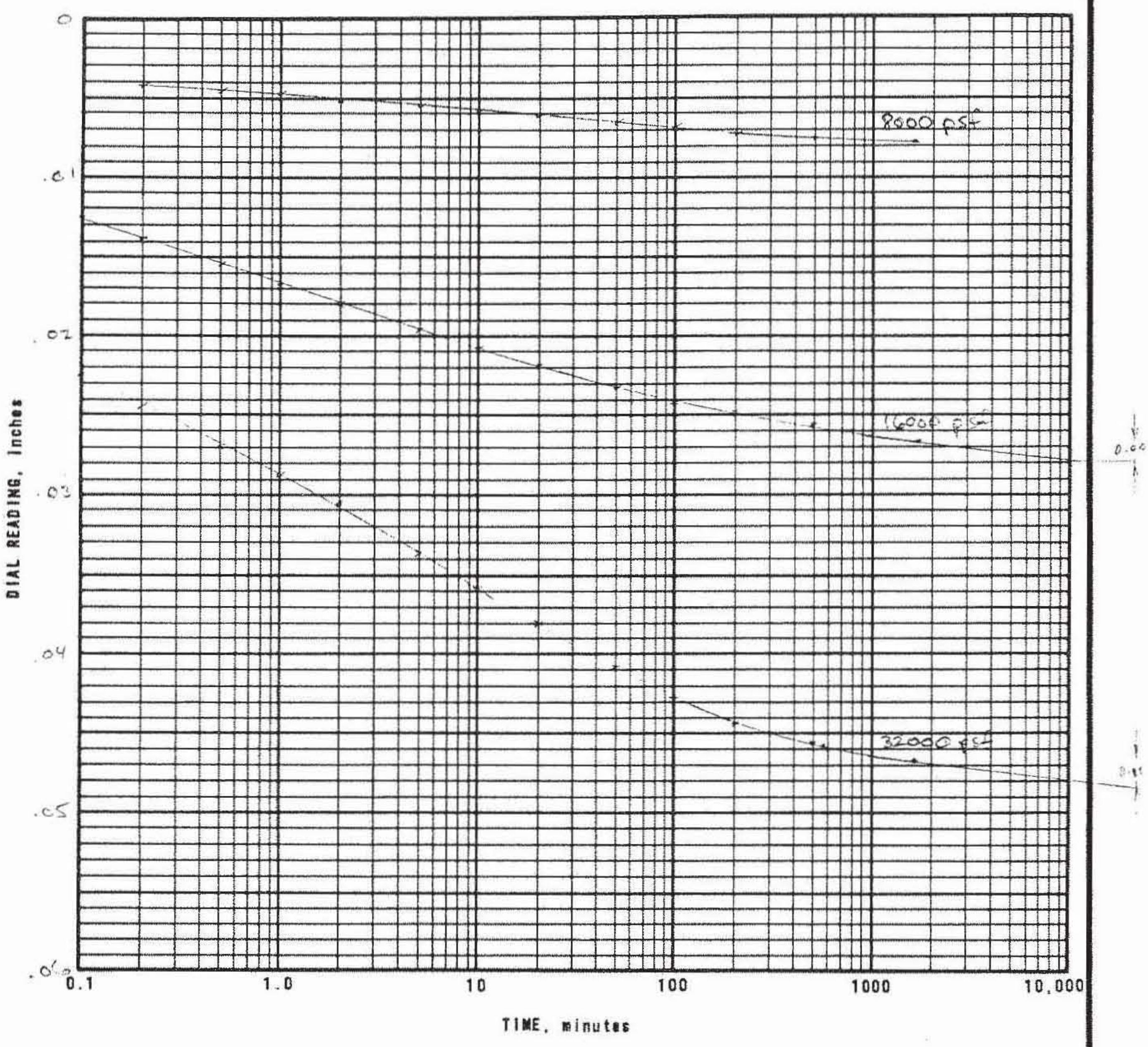
DESCRIPTION : silty CLAYSTONE, yellow brn (CH)
LIQUID LIMIT : 82
PLASTIC LIMIT : 54

	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	PERCENT SATURATION	VOID RATIO
INITIAL	27.3	93.1	86	.906
FINAL	29.9	95.9	100	.851

FIG. 2

Remark : July 1990

Project ESK-101A	Kettleman
Wahler Associates	CONSOLIDATION TEST Figure No.

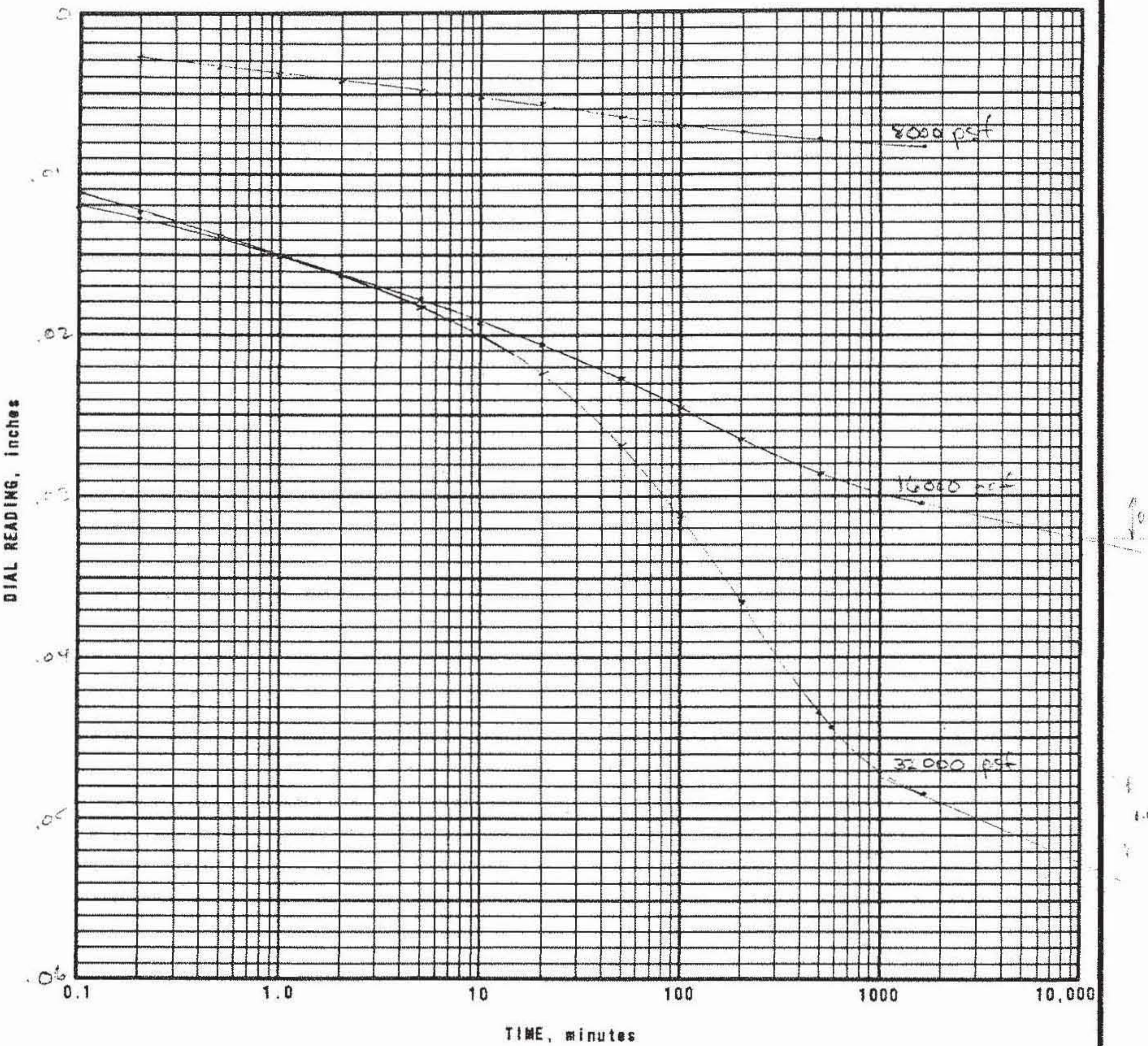


DT-C, B-1, 8'

FIG. 3

WAHLER ASSOCIATES	Kettleman	CONSOLIDATION TEST TIME – COMPRESSION CURVES		
		PROJECT NO.	DATE	FIGURE NO.
	PALO ALTO • [redacted] • CALIF.	ESK 101A	7/90	

VRI - 8-16-90



DT. A, B-2, 5'

FIG. 4

WAHLER ASSOCIATES	Kettleman	CONSOLIDATION TEST TIME - COMPRESSION CURVES		
		PROJECT NO.	DATE	FIGURE NO.
PALO ALTO • [redacted] • CALIF.		ESK 101A	7/90	

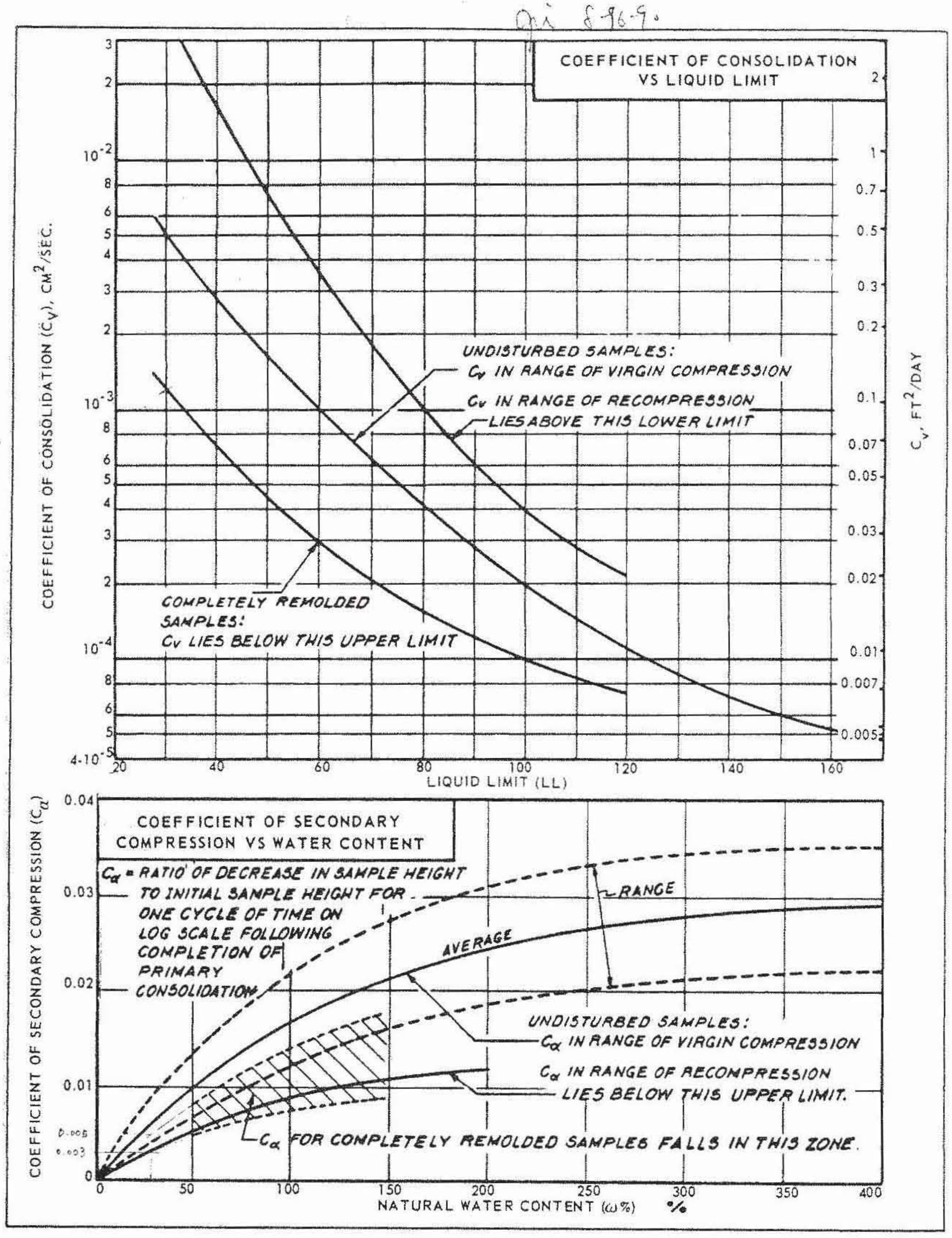


FIGURE 3-5

Approximate Correlations for Consolidation Characteristics of Silts and Clays

Ref : NAVFAC, DM-7

APPENDIX G.4
POST-CLOSURE WASTE SETTLEMENT

Golder Associates	Kettleman Hills Facility – Landfill Unit B-18 POST-CLOSURE WASTE SETTLEMENT	
	Project No.: 083-91887	Made By: LAQ
	Date: 05-28-2008	Checked By: EH
	Sheet: 1 of 1	Reviewed By:

Objective:

1. To estimate the effects of secondary settlement of the waste fill on the landfill cover post-closure grade for drainage.
2. Utilize Environmental Solutions Inc. (ESI) original calculation methods and assumptions and apply them to the new expansion configuration.

Given:

For the new landfill expansion geometry and as-built landfill configuration used to generate the evaluated sections where obtained from AutoCAD drawings (see Drawings 1 through 6 in Appendix G-1). All other data used for these calculations are based on the original Environmental Solutions Inc. (ESI) calculation, including site geology and foundation stratigraphy (see Attachment 1).

Assumptions and Methods:

All assumptions and methods utilized on this calculation are based on the ESI original calculation dated August 14, 1990. ESI calculations are included in Attachment 1.

Calculations and Results:

Calculation methods are described on ESI original calculation dated August 14, 1990. Calculations are shown in Attachment 1. Results for the new calculations are attached in Table 1 to 4. The calculations indicate the post-closure settlement will be approximately 9.3% of the waste thickness.

Conclusions:

As stated by ESI in their original calculation; "Based on the final cover post-closure settlement calculations for the selected sections, the results indicate that the changes of the grade after settlement will have no adverse effect on the surface drainage. After settlement, the gradients are still more than 3% which is the minimum requirement for drainage." Based on a review of ESI's calculations, Golder agrees with their original conclusions. In some cases shown in Table 3 the apparent gradient is less than 3%. The locations resulting in a value less than the required 3% are due to the location of the selected section not being nearly perpendicular to the new cover drainage slope. By observation and comparison with Section 2-2', these locations maintain a minimum 3% true slope.

As stated by ESI in their original calculation, "Due to the geometry of the final cover it is expected that the length of the slopes in the soil cover and liner systems will be reduced due to settlement. A minimal reduction strain is expected and should be readily absorbed by the soil cover and the liner systems without causing any damage".

Reference:

Environmental Solutions Inc. "Engineering and Design report Landfill Unit B-18 Phase 1, 2 and Final Closure, Kettleman Hills Facility". August 1990. Appendix G.4

Table 1
Post-Closure Waste Settlement
Section 1-1'

Assumptions:

Containers in waste:	0.15 %
Containers Voids:	0.10 %
H_{waste}:	280 ft
γ_{waste}:	115 pcf
E_{waste}:	40,000 psf
C_α:	0.02
W_{waste}:	14,500,000 cy^3
Incoming Waste:	550,000 cy^3/yr
Stages:	5
Post-Closure period:	30 yr

$S_T = S_C + S_V + S_D + S_S$

S_C	0.0%
S_V	1.5%
S_D	6.0%
S_S	1.7%
S_T	9.3%
T	27 yr
t	5.40 yr

S_{D1} 40%

Stage	t_1(yr)	t_2(yr)	log t_1/t_2	C_α	δH	
1	5.4	51.6	0.98	0.02	0.0039	H
2	5.4	46.2	0.93	0.02	0.0037	H
3	5.4	40.8	0.88	0.02	0.0035	H
4	5.4	35.4	0.82	0.02	0.0033	H
5	5.4	30.0	0.74	0.02	0.0030	H
				$\Delta\sigma$	0.0174	H

Final Grade Calculation

Station	Finish Elevation (ft)	Waste Thickness (ft)	ΔH 0.093H (ft)	Final Elevation (ft)	Distance (ft)	Initial Grade (%)	Final Grade (%)
1	806.18	0	0.00	806.18			
					375.43	24.6%	20.4%
2	898.62	171.15	15.88	882.74			
					419.64	23.5%	21.4%
3	997.29	268.59	24.92	972.37			
					49.85	19.2%	19.3%
4	1006.88	268.29	24.89	981.99			
					49.85	20.9%	20.6%
5	996.47	266.67	24.74	971.73			
					212.15	21.5%	15.9%
6	950.83	137.61	12.77	938.06			
					240.09	21.9%	16.6%
7	898.32	0	0.00	898.32			

Note: See Drawing 1 and 2 in Appendix G-1 for Section location and Drawing 3 for Cross Section profile.

Table 2
Post-Closure Waste Settlement
Section 2-2'

Assumptions:

Containers in waste:	0.15 %
Containers Voids:	0.10 %
H_{waste}:	280 ft
γ_{waste}:	115 pcf
E_{waste}:	40,000 psf
C_{α}:	0.02
W_{waste}:	14,500,000 cy^3
Incoming Waste:	550,000 cy^3/yr
Stages:	5
Post-Closure period:	30 yr

$S_T = S_C + S_V + S_D + S_S$

S_C	0.0%
S_V	1.5%
S_D	6.0%
S_S	1.7%
S_T	9.3%
T	27 yr
t	5.40 yr

S_{D1} 40.3%

Stage	t_1(yr)	t_2(yr)	log t_1/t_2	C_{α}	δH	
1	5.4	51.6	0.98	0.02	0.0039	H
2	5.4	46.2	0.93	0.02	0.0037	H
3	5.4	40.8	0.88	0.02	0.0035	H
4	5.4	35.4	0.82	0.02	0.0033	H
5	5.4	30.0	0.74	0.02	0.0030	H
				$\Delta\sigma$	0.0174	H

Final Grade Calculation

Station	Finish Elevation (ft)	Waste Thickness (ft)	ΔH 0.093H (ft)	Final Elevation (ft)	Distance (ft)	Initial Grade (%)	Final Grade (%)
1	771.69	0	0.00	771.69			
					290	24.2%	18.8%
2	842.00	171.5	15.91	826.09			
					392.34	23.9%	21.6%
3	935.86	268.59	24.92	910.94			
					484.83	15.3%	15.8%
4	1010.00	243.40	22.58	987.42			
					143.86	5.6%	3.1%
5	1018.00	281.55	26.12	991.88			
					114.56	7.0%	5.4%
6	1010.00	261.98	24.31	985.69			
					168.02	23.7%	17.0%
7	970.20	141.19	13.10	957.10			
					254.12	23.7%	18.5%
8	910.00	0	0.00	910.00			

Note: See Drawing 1 and 2 in Appendix G-1 for Section location and Drawing 4 for Cross Section profile.

Table 3
Post-Closure Waste Settlement
Section 3-3'

Assumptions:

Containers in waste:	0.15 %
Containers Voids:	0.10 %
H_{waste}:	280 ft
γ_{waste}:	115 pcf
E_{waste}:	40,000 psf
C_α:	0.02
W_{waste}:	14,500,000 cy^3
Incoming Waste:	550,000 cy^3/yr
Stages:	5
Post-Closure period:	30 yr

$S_T = S_C + S_V + S_D + S_S$

S_C	0.0%
S_V	1.5%
S_D	6.0%
S_S	1.7%
S_T	9.3%
T	27 yr
t	5.40 yr

S_{D1} 40.3%

Stage	t_1(yr)	t_2(yr)	log t_1/t_2	C_α	δH	
1	5.4	51.6	0.98	0.02	0.0039	H
2	5.4	46.2	0.93	0.02	0.0037	H
3	5.4	40.8	0.88	0.02	0.0035	H
4	5.4	35.4	0.82	0.02	0.0033	H
5	5.4	30.0	0.74	0.02	0.0030	H
				Δσ	0.0174	H

Final Grade Calculation

Station	Finish Elevation (ft)	Waste Thickness (ft)	ΔH 0.093H (ft)	Final Elevation (ft)	Distance (ft)	Initial Grade (%)	Final Grade[1] (%)
1	890.51	0	0.00	890.51			
					252.19	23.7%	17.4%
2	950.18	169.36	15.71	934.47			
					252.17	19.8%	16.1%
3	1000.00	268.31	24.89	975.11			
					227.75	6.3%	5.9%
4	1014.46	278.29	25.82	988.64			
					181.73	crossing ridge of top deck	
5	1012.84	285.82	26.52	986.32			
					341.58	crossing ridge of top deck	
6	1007.53	273.53	25.38	982.15			
					146.71	crossing ridge of top deck	
7	1006.62	279.34	25.92	980.70			
					364.03	22.8%	20.4%
8	923.48	185.27	17.19	906.29			
					301.74	24.4%	18.7%
9	850	0	0.00	850.00			

Notes: See Drawing 1 and 2 in Appendix G-1 for Section location and Drawing 5 for Cross Section profile.

Points 4, 5 and 6 currently cross the ridge line of the top deck and therefore do not reflect true slope. Secion 2-2' provides points across the top deck that are along true slope.

Table 4
Post-Closure Waste Settlement
Section 4-4'

Assumptions:

Containers in waste:	0.15 %
Containers Voids:	0.10 %
H_{waste}:	280 ft
γ_{waste}:	115 pcf
E_{waste}:	40,000 psf
C_{α}:	0.02
W_{waste}:	14,500,000 cy^3
Incoming Waste:	550,000 cy^3/yr
Stages:	5
Post-Closure period:	30 yr

$S_T = S_C + S_V + S_D + S_S$

S_C	0.0%
S_V	1.5%
S_D	6.0%
S_S	1.7%
S_T	9.3%
T	27 yr
t	5.40 yr

S_{D1} 40.3%

Stage	t_1(yr)	t_2(yr)	log t_1/t_2	C_{α}	δH	
1	5.4	51.6	0.98	0.02	0.0039	H
2	5.4	46.2	0.93	0.02	0.0037	H
3	5.4	40.8	0.88	0.02	0.0035	H
4	5.4	35.4	0.82	0.02	0.0033	H
5	5.4	30.0	0.74	0.02	0.0030	H
				$\Delta\sigma$	0.0174	H

Final Grade Calculation

Station	Finish Elevation (ft)	Waste Thickness (ft)	ΔH 0.093H (ft)	Final Elevation (ft)	Distance (ft)	Initial Grade (%)	Final Grade (%)
1	848.28	0.00	0.00	848.28			
					193.06	24.2%	17.9%
2	895.07	131.82	12.23	882.84			
					271.02	24.2%	20.4%
3	960.64	243.47	22.59	938.05			
					148.6	7.6%	6.9%
4	971.89	254.54	23.62	948.27			
					114.97	11.7%	10.3%
5	958.46	237.72	22.06	936.40			
					310.89	24.3%	22.2%
6	882.96	168.21	15.61	867.35			
					346.76	24.0%	19.5%
7	799.63	0.00	0.00	799.63			

See Drawing 1 and 2 in Appendix G-1 for Section location and Drawing 6 for Cross Section profile.

Attachment 1

ESI Settlement Calculations

ENVIRONMENTAL SOLUTIONS, INC.

By N.A. Date 8-10-90 Subject LANDFILL B-18 FINAL COVER POST-CLOSURE SETTLEMENT Sheet No.____ of____

Chkd. By GSC Date 8/14/90 Proj. No. 89-977

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ENVIRONMENTAL SOLUTIONS, INC.

By VR/NA/GSC Date 7-12-90 Subject LANDFILL B-18 FINAL COVER Sheet No. 1 of 14
Chkd. By GSC Date 8/14/90 POST-CLOSURE GRADE EVALUATION Proj. No. 89-977

PURPOSE: TO EVALUATE THE EFFECT OF SECONDARY SETTLEMENT OF THE WASTE FILL ON THE LANDFILL COVER POST-CLOSURE GRADE FOR DRAINAGE.

REFERENCE:

1. SOIL MECHANICS, LAMBE & WHITMAN (Figure 1)
2. NAVFAC DM 7-1, (Figure 2)
3. WASTE SETTLEMENT REPORT FOR FINAL LANDFILL COVER DESIGN, GOLDER ASSOCIATES INC., JULY 1989
4. W.L. Murphy and P.A. Gilbert (1985) "Settlement and cover subsidence of Hazardous Waste Landfills"

ENVIRONMENTAL SOLUTIONS, INC.

By GSC Date 8/10/90 Subject WASTE SETTLEMENT Sheet No. 2 of 14

Chkd. By ___ Date ___ KETTLEMAN HILL, B-18 LANDFILL Proj. No. 89-977

Objective : To evaluate the waste settlement behavior and parameters for waste settlement analysis. The results of the waste settlement analysis will be used to determine the influence of final grade of the final cover after closure of the landfill.

REF : (1) W.L. Murphy and P.A. Gilbert (1985) "Settlement and Cover Subsidence of Hazardous Waste Landfills"

DISCUSSION : TOTAL SETTLEMENT OF LANDFILL

$$S_T = S_c + S_v + S_D + S_s$$

WHERE S_c = CONSOLIDATION SETTLEMENT OF BULK WASTE

S_V = SETTLEMENT DUE TO COLLAPSE OF VOIDS INSIDE WASTE CONTAINERS

S_D = SETTLEMENT DUE TO CONTAINER WASTES AFTER CONTAINERS CORRODED AND COLLAPSE

S_s = SECONDARY SETTLEMENT OF WASTE DUE TO CREEP.

IT IS EXPECTED THAT THE CONSOLIDATION SETTLEMENT WILL BE ESSENTIALLY COMPLETE BEFORE THE FINAL CLOSURE. THEREFORE THE CONSOLIDATION SETTLEMENT IS NOT NECESSARY TO BE INCLUDED IN THIS EVALUATION WHICH WILL BE USED TO DETERMINE THE FINAL COVER INFLUENCE. THE FOLLOWING EVALUATION WILL ONLY INCLUDE THE DETERMINATION OF S_V & S_D. S_s HAS DETERMINED PREVIOUSLY (SEE ATTACHMENT) USING THE CORRELATION OF C_α V.S. WATER CONTENT OF

ENVIRONMENTAL SOLUTIONS, INC.

By G. Chou Date 8/10/90 Subject Waste Settlement Sheet No. 3 of 14
Chkd. By ____ Date ________ Kettleman Hill, B-18 Landfill Proj. No. 89-977

NORMALLY CONSOLIDATED CLAY.

ASSUMPTION : (1) BASED ON CHEM. WASTE OFFICALS, THE AMOUNT OF CONTAINERIZED WASTE CONTAINED IN THE B-18 LANDFILL IS EXPECTED TO BE APPROXIMATELY 15%

(2) THE % OF VOIDS IN THE CONTAINER IS EXPECTED TO HAVE AT MOST 10% OF THE CONTAINER VOLUME.

(3) ASSUME THE DRUM CONTAINER WILL BE EVENLY DISTRIBUTED IN THE LANDFILL DURING THE LIFE OF THE LANDFILL OPERTION.

(4) ASSUME ALL CONTAINER WILL BE INTACTED DURING THE PERIOD OF LANDFILL OPERATION. THEREFORE ALL SETTLEMENT CAUSED BY DRUM WASTE WILL OCCUR AFTER CLOSURE AND WILL DIRECTLY AFFECT THE FINAL COVER.

CALCULATION :

* S_v (Collapse of containers voids)
$= 0.10 \times 0.15$
$= 0.015$ or 1.5% OF THE TOTAL WASTE HEIGHT

* S_D (settlement of waste inside drums)
BECAUSE THE WASTE DRUM ARE EVENLY DISTRIBUTED, THE AVERAGE STRESS TO THE WASTE INSIDE THE DRUMS AFTER THE DRUMS CORRODED IS
$115\ pcf \times 210 \left(\frac{1}{2}\right)$ WHERE 210' IS THE TOTAL EXPECTED HEIGHT OF WASTE

ENVIRONMENTAL SOLUTIONS, INC.

By G. CHOU Date 8/10/90 Subject Waste settlement Sheet No. 4 of 14
Chkd. By ___ Date ___ Kettleman Hill, B-18 Landfill Proj. No. 87-977

$\therefore S_D = 115 \times \frac{210}{2} \times \frac{1}{E}$

WHERE $E = 40{,}000\,psf$ (REF. 1)

$S_D = \frac{115 \times 105}{40{,}000} = 0.30$ or 30% OF THE DRUM WASTE

SINCE THE DRUM WASTE IS ONLY 15% OF THE WASTE

$S_D = 0.30 \times 0.15 = 0.045$ or 4.5% OF THE TOTAL WASTE HEIGHT

* $S_S = 0.02$ or 2% OF THE TOTAL WASTE HEIGHT (See page 5 & 6)

TOTAL SETTLEMENT AFTER CLOSURE

$S_T = 0.015 + 0.045 + 0.02$

$= 0.075$ or 7.5% OF THE TOTAL HEIGHT

CONCLUSION :

USE 7.5% OF THE TOTAL HEIGHT TO CALCULATE SETTLEMENT AFTER CLOSURE.

SETTLEMENT CHARACTERISTICS OF THE WASTE FILL IS SIMILAR TO THE BEHAVIOR OF NORMALLY CONSOLIDATED CLAY.

THE SECONDARY SETTLEMENT MAY BE ESTIMATED BY THE FOLLOWING EQUATION.

$$\Delta_s = C_\alpha H \log \frac{t_2}{t_1}$$

WHERE

C_α = RATE OF SECONDARY COMPRESSION

H = THICKNESS OF THE SOIL LAYER

t_2 = FINAL TIME

t_1 = INITIAL TIME (time when primary consolidation completes)

TYPICAL VALUES OF C_α FOR NORMALLY CONSOLIDATED CLAY VARY FROM 0.005 TO 0.02. Ref. 1 (see fig. 1) BY ASSUMING THE NATURAL MOISTURE CONTENT OF THE WASTE FILL RANGES FROM 30 TO 40 %, THE VALUE OF C_α IS ESTIMATED TO BE ABOUT 0.003 TO 0.004. Ref. 2 (see fig. 2) TO BE CONSERVATIVE, A CONSTANT VALUE OF 0.02 WILL BE USED.

ENVIRONMENTAL SOLUTIONS, INC.

By opi Date 7-17-90 Subject LANDFILL B-18 FINAL COVER Sheet No. 6 of 14

Chkd. By GSC Date 8/14/90 POST-CLOSURE GRADE EVALUATION Proj. No. 89-977

ESTIMATE OF SECONDARY CONSOLIDATION OF WASTE FILL

TOTAL VOLUME OF B-18 $\approx 9.5 \times 10^6$ cy

ASSUME INCOMING WASTE IS ABOUT 500,000 cy/YEAR.

$\therefore$ OPERATIONAL LIFE OF B-18

$$T = \frac{9.5 \times 10^6}{500000} = 19 \text{ YEARS}$$

DIVIDE THE FULL OPERATIONAL LIFE OF THE LANDFILL INTO 5 STAGES, THE OPERATIONAL LIFE FOR EACH STAGE

$t = \frac{19}{5} = 3.8$ YEARS Assuming primary consolidation completed at the end of each stage

FOR A TYPICAL 30-YEAR POST-CLOSURE PERIOD, THE THE SECONDARY SETTLEMENT OF EACH STAGE

STAGE	FINAL TIME	$\log t_2/t_1$	C_d	$\delta = \frac{H}{t} c_d \log t_2/t_1$
1	45.2	$\log 45.2/3.8$	0.02	0.0043
2	41.4	$\log 41.4/3.8$	0.02	0.0041
3	37.6	$\log 37.6/3.8$	0.02	0.0040
4	33.8	$\log 33.8/3.8$	0.02	0.0038
5	30	$\log 30/3.8$	0.02	0.0036

Δ_S 0.0198 H $\approx$ 2%

Figure. 1 7/14

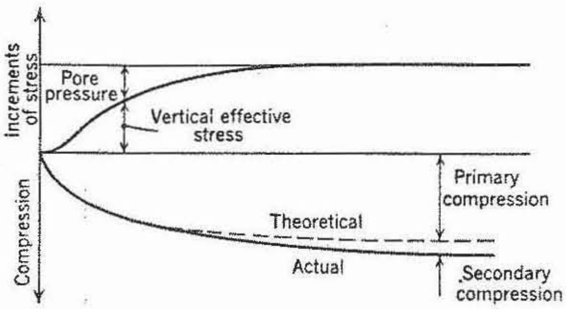

Fig. 27.14 Primary and secondary compression.

skeleton. The relative importance of primary and secondary compression depend on the time required to dissipate pore pressures and hence on the thickness of the soil.

The relative importance of secondary and primary compression varies with the type of soil and also with the ratio of stress increment to initial stress.

The magnitude of secondary compression is often expressed by the slope C_α of the final portion of the time compression curve on semi-log paper (Fig. 27.17). Table 27.2 gives typical values for this slope C_α. The

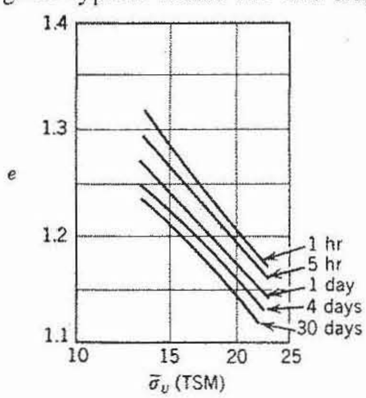

Fig. 27.15 e versus log $\bar{\sigma}_v$ as function of duration of secondary compression (After Bjerrum, 1967).

time rate of secondary compression is largest for highly plastic soils and especially for organic soils.

The ratio of secondary to primary compression is largest when the ratio of stress increment to initial stress is small. This is illustrated in Fig. 27.18, which shows that the usual form of time-compression curve occurs only when the stress increment is large. Fortunately, most problems involving important settlements involve relatively large increments of stress.

Taylor (1942) was the first person to propose a rational theory of secondary compression. This theory modeled the soil skeleton as a viscoelastic material. Recent work in this area is directed at the developing models of behavior and numerical techniques for solving secondary compression problems with complicated rheologic models.

The phenomenon of secondary compression greatly complicates prediction of the time history and final magnitude of settlement. Bjerrum (1967) has discussed this subject. Secondary compression also makes it difficult to determine c_v accurately from laboratory tests.

27.8 SUMMARY OF MAIN POINTS

1. The differential equation of continuity, which is the basis for the study of consolidation, equates the *net* flow to the change in volume of the soil.

Table 27.2 Typical Values for Rate of Secondary Compression C_α

	C_α
Normally consolidated clays	0.005 to 0.02
Very plastic soils; organic soils	0.03 or higher
Precompressed clays with OCR > 2	less than 0.001

From Ladd, 1967.

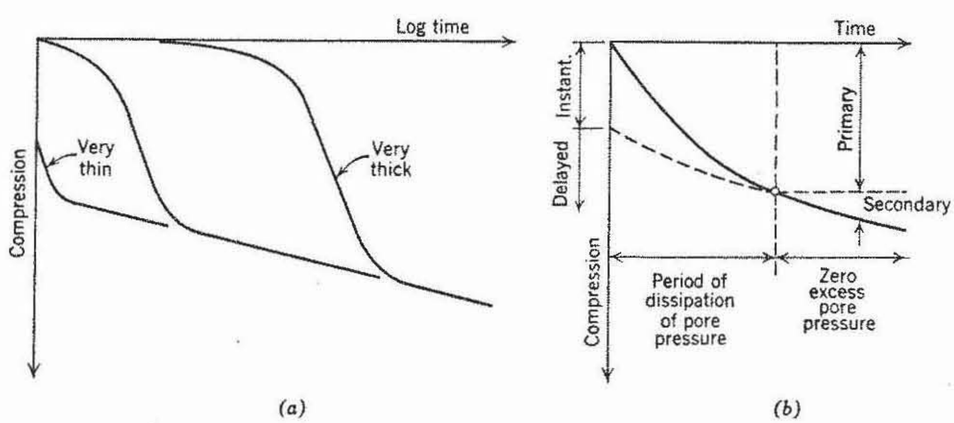

Fig. 27.16 Relation of instantaneous and delayed compression to primary and secondary compression. (*a*) For different thicknesses. (*b*) For a given thickness.

Ref: Soil Mechanics Lambe & Whitman

Figure 2

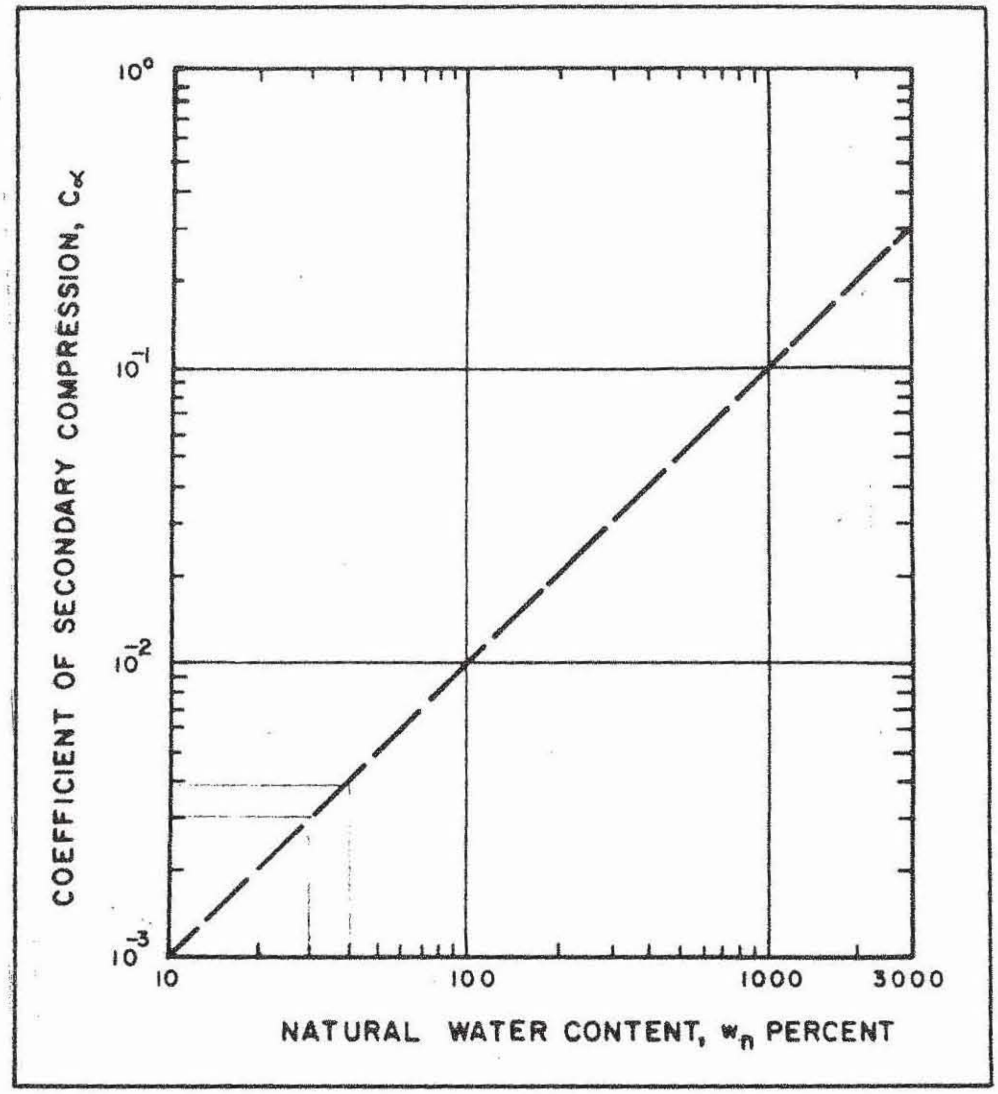

FIGURE 16
Coefficient of Secondary Compression as Related to Natural Water Content

Ref! NAVFAC DM 7-1

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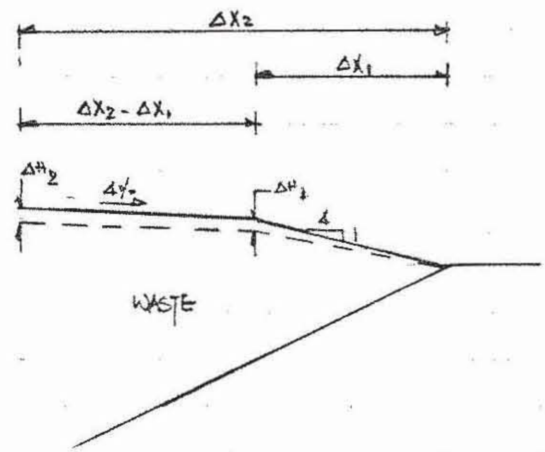
THE FINAL GRADE ON THE LANDFILL COVER BETWEEN ANY TWO POINTS MAY BE CALCULATED AS FOLLOW:

$$G_f = \frac{(EL_2 - \Delta H_2) - (EL_1 - \Delta H_1)}{(\Delta X_2 - \Delta X_1)}$$



WHERE

EL_2 = ELEVATION AT POINT 2

EL_1 : ELEVATION AT POINT 1

ΔH_2 = SETTLEMENT AT POINT 2

ΔH_1 = SETTLEMENT AT POINT 1

$(\Delta X_2 - \Delta X_1)$ = DISTANCE BETWEEN 2 POINTS

Total settlement after closure = 0.075 of the Total Ht.

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SECTION 1

STATION	FINISH ELEVATION (FT)	WASTE THICKNESS (FT)	ΔH 0.075 H (FT)	FINAL ELEVATION (FT)	DISTANCE (FT)	FINAL GRADE %
1	810	0	0	810		
					165	19.9
2	850	95	7.13	842.87		
					440	23.4
3	960	190	14.25	945.75		
					35	3.1
4	962.2	205	15.38	946.82		
					35	9.1
5	960	218	16.35	943.65		
					440	21.8
6	850	28	2.1	847.9		
					40	19.8
7	840	0	0	840		

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SECTION 2

STATION	FINISH ELEVATION (FT)	WASTE THICKNESS (FT)	ΔH 0.075 H (FT)	FINAL ELEVATION (FT)	DISTANCE (FT)	FINAL GRADE %
1	770	0	0	770		
					335	20.5
2	850	150	11.25	838.75		
					350	22.6
3	935	230	17.25	917.75		
					170	13.7
4	960	252	18.9	941.1		
					140	6.5
5	968.25	240	18	950.25		
					135	3.4
6	960	190	14.25	945.75		
					440	22.4
7	850	38	2.85	847.15		
					55	22.1
8	835	0	0	835.0		

SECTION 3

STATION	ELEVATION (FT)	WASTE THICKNESS (FT)	ΔH 0.075 H (FT)	FINAL ELEVATION (FT)	DISTANCE (FT)	FINAL GRADE %
1	830	0	0	830		
					85	18.7
2	850	55	4.13	845.87		
					165	20.15
3	890	145	10.88	879.12		
					470	3.8
4	910	175	13.13	896.87		
					450	6.1
5	940	210	15.75	924.25		
					220	8.5
6	920	192	14.4	905.6		
					205	0*
7	920	190	14.25	905.75		
					285	19.8
8	850	10	0.75	849.25		
					15	28.3
9	845	0	0	845		

* Refer to Attachment A section on plan view, section not nearly perpendicular to the drain slope.

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SECTION 4

STATION	ELEVATION (FT)	WASTE THICKNESS (FT)	ΔH 0.075 H (FT)	FINAL ELEVATION (FT)	DISTANCE (FT)	FINAL GRADE %
1	808	0	0	808		
					175	19.3
2	850	110	8.25	841.75		
					440	22.5
3	960	255	19.13	940.87		
					440	23.2
4	850	150	11.3	838.7		
					275	14.1
5	800	0	0	800		

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Chkd. By ESC Date 8/14/90 Proj. No. 89-977

Based on the final cover post-closure settlement calculations for the four sections. The results indicate change of grade after settlement will have no adverse effect on surface drainage.

After settlement the gradients are still more than 3% which is the mini. requirement for drainage.

A summary for final cover Post-closure grade evaluation is shown on pages 10-13 for sections 1-4

Due to the geometry of the final cover, the length of the slope will be reduced due to the settlement and thus the liner. The reduce in strain is expected to be small and will be readily absorbted by the soil cover and the liner without causing damage to the system.